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DIRECT LARYNGOSCOPY, BRONCHOSCOPY, AND ŒSOPHAGOSCOPY

DIRECT LARYNGOSCOPY, BRONCHOSCOPY, AND ŒSOPHAGOSCOPY

BY

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ETC., ETC.

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1912

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AUTHOR'S PREFACE

THE present book is a revised and expanded form of my "Handbuch für die Technik und Methodik der direkten Okularen Methoden," which was published in 1910.

The first section of this book, "Die Technik," has for the most part been omitted. It dealt with the theoretical considerations underlying the construction of my instruments, which up to that time had no chance of a widespread recognition. Since, however, by now more than 1,000 of these are in use, and are familiar to most endoscopists, the theoretical considerations would seem superfluous.

The space that has been gained by omitting this part of the book has been utilized to expand that part dealing with the method itself in its clinical application. In this connection I may say that the section dealing with direct operations on the Larynx has been completely rewritten, and an entirely new chapter on Bronchoscopic Operations and methods of treatment has been added. In this an exhaustive and systematic account has been given of the diagnosis and treatment of bronchial foreign bodies, and the further question of endobronchial therapeutics has been discussed. It is hoped that these alterations and additions will add to the practical value of the book, and will enable the reader to obtain a methodical idea of the subject, so that he can approach even his first attempt at broncho-œsophageal manipulation with the feeling of certain success.

For the skilled observer there are many wearisome details that might well have been omitted, but daily experience in my endoscopic classes has convinced me that the written description must include the most elementary details, if it is in any way to replace personal instruction. I can only hope that the book may be as favourably received in England as it has been here, and I should like to take this opportunity of recording the debt of gratitude which I owe to my colleague, Mr. Howarth, for the great care and understanding which he has bestowed on the laborious work of translation.

W. BRÜNINGS.

JENA.
December, 1911.

TRANSLATOR'S PREFACE

During the process of translating Dr. Brünings' well-known work, which has become a standard textbook on the Continent, I became convinced that the rapid advance of the study and application of bronchoscopy called for a book in English which should combine the technical and the clinical sides of the subject. As Dr. Brünings' book, which dealt exhaustively with the technical side, was intended to serve as a preliminary to a clinical treatise on the subject, I discussed with him the possibility of compressing the technical side and expanding the work by the addition of a section which should embody the most recent clinical experience. Dr. Brünings readily fell in with my suggestions, both in principle and in detail, with the result that about one-third of the matter in the present work is entirely new, and both sides of the subject receive due treatment. The new matter in the book embodies Dr. Brünings' enormous practical experience, which, in my opinion, cannot fail to give additional impetus to the more widespread application of bronchoscopy, which his mechanical ingenuity has done so much to simplify.

W. G. HOWARTH.

Harley Street, W.,
January, 1912.

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DIRECT LARYNGOSCOPY, BRONCHOSCOPY, AND ŒSOPHAGOSCOPY

CHAPTER I

ENDOSCOPIC TECHNIQUE

THE examination of the air-passages and œsophagus by the direct method makes very heavy demands on the skill of the surgeon and the endurance of the patient. It is therefore most advisable, on both grounds, that the first attempts on the living subject should be preceded and facilitated by a thorough preparation in everything that concerns the method.

I consider that this should include not only practice on the dummy and examinations conducted on animals and on the cadaver, but should also embrace an exact knowledge of the entire endoscopic apparatus, which is, unfortunately, very complicated, and should presuppose a certain familiarity with the management of the component parts. This chapter will be devoted to these considerations. In my practical courses on endoscopy I am careful to lay great stress on the importance of these preparatory exercises in technique, as I consider that an acquaintance with them is more likely to place the surgeon in a position to meet the many unexpected demands of practice than is the single introduction of the tube on a practised patient or medium.

I will begin with an account of a complete endoscopic outfit and of the various pieces of accessory apparatus.

1. REVIEW OF THE INSTRUMENTS REQUIRED.

In order to dispose of the question of a complete instrumental equipment, I will first describe the composition of the normal instrumentarium, and will then enumerate the most useful supplementary instruments.

After that I will refer to practice exercises on the dummy and the important question of electric current.

Normal Instrumentarium and Accessory Apparatus.

The relative simplicity and cheapness of my instrumentarium for broncho-œsophagoscopy makes the former division into "small," "medium," and "large," no longer necessary, and, indeed, the present normal outfit subserves a wider range than even the "large" size of the older outfit.

A really complete endoscopic outfit does not exist. Even my "normal" equipment is only a compromise in the sense that every universal instrumentarium must be a compromise. Nevertheless, it is possible to perform with it at least nine-tenths of the tasks which present themselves—perhaps even ninety-nine-hundredths, when it is considered that for every single time it is used for an operation it may be estimated that it is used twenty times for diagnostic purposes.

The current remark that there are to-day far more bronchoscopic instruments than cases of foreign bodies in the bronchus, only proves how incomplete, even now, is the knowledge and appreciation of the many-sided service that the direct method can achieve. In no case should this view beguile the surgeon into being willing to put up with a couple of instruments selected at random, for in medical matters an insufficient equipment is often worse than none at all. I cannot, therefore, agree with Jackson,* when he writes, "If rigid economy must be practised, much good work can be done with a 7-millimetre by 45-centimetre œsophagoscope, a 5-millimetre by 30-centimetre bronchoscope, and a 12-millimetre by 17-centimetre separable speculum."

The normal equipment consists of the following separate parts:

1. The electroscope, with supplementary lamp and aseptic cord.
2. The double extension tubes, Nos. 1-5. No. 1 (14 millimetres) for œsophagoscopy. No. 2 (12 millimetres) for bronchoscopy, with a

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* Chevalier Jackson, 'Tracheobronchoscopy,' etc. St. Louis, 1907.

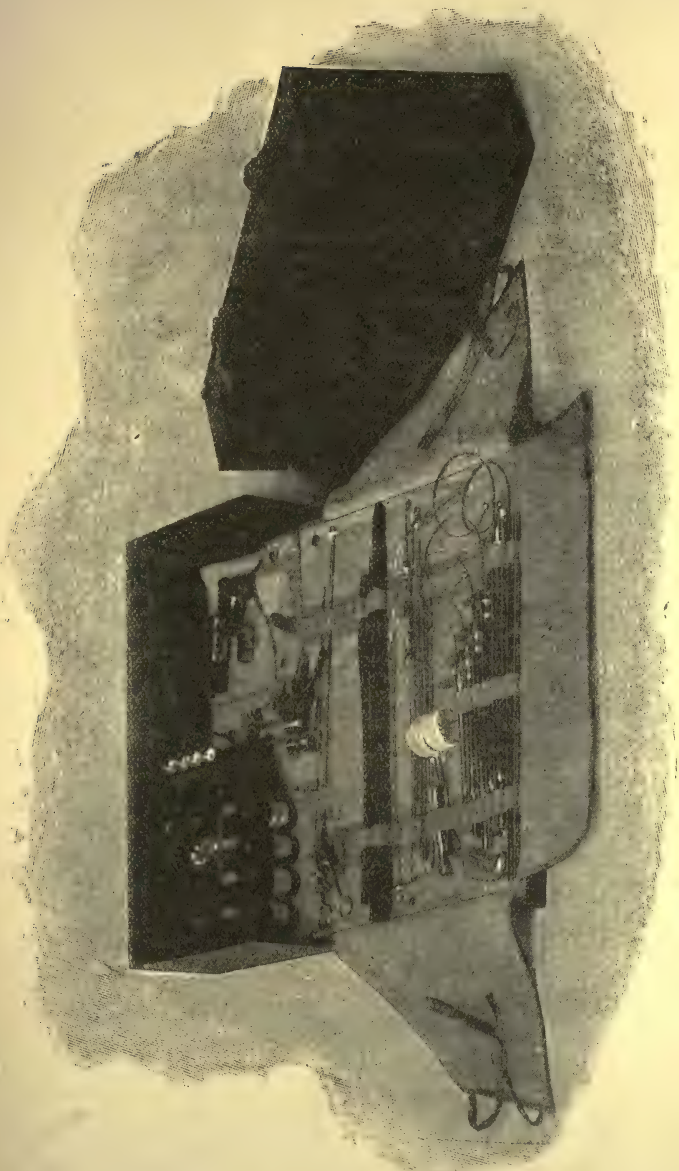

FIG. 1.—NORMAL BRONCHO-ŒSOPHAGOSCOPIC INSTRUMENTARIUM IN CASE.

second long unperforated sliding tube for œsophagoscopy. Nos. 3-5 (10, 8·5, and 7 millimetres) for bronchoscopy.

3. Two autoscopy spatulæ of 13 and 11 millimetres diameter. One autoscopy spatula for children.
4. Special bougies for tubes 1, 2, and 3.
5. Two bronchoscopic forceps, 25 and 35 centimetres long, with five interchangeable end-pieces.
6. One œsophagoscopic forceps, 50 centimetres long, with two interchangeable end-pieces.
7. A saliva pump with three tubes, 25, 35, and 50 centimetres in length.
8. Two hooks for foreign bodies.
9. One dozen double wool-carriers.

And, unless the utmost economy is demanded, I would recommend in addition,

10. One extension tube of a diameter between Nos. 4 and 5—that is, about 7·75 millimetres.
11 One counter-pressure instrument (useful with operation instruments).
12. One short, specially strong clutch forceps for foreign bodies firmly fixed at the entrance to the gullet.
13. A combined syringe and drug applicator, with three end-pieces for anæsthetizing the larynx and the bronchi (see p. 63).
14. A glass jar for keeping the forceps in soap spirit (see p. 48).
15. Rectangular spatula for trial autoscopy (see p. 94).

It is possible to leave out, as chiefly allocated to hypopharyngo-œsophagoscopy,

From No. 2, the 14-millimetre tube, the unfenestrated 12-millimetre extension tube.
No. 4.
No. 6.
From No. 7, the 50-centimetre tube.
No. 11.

For carrying about, this normal instrumentarium (with the exception of the glass jars) can be packed in a handy case with a sterilizable lining. The long wool-carriers and pump-tubes can be taken to pieces, so that the total length of the box only measures 40 centimetres. The box also contains bottles for 20 per cent. and 10 per cent. cocaine, adrenalin, and paraffin, and enough room for a head-mirror, laryngeal mirrors, wool, anæsthetics, antiseptics, etc. For the sake of completeness, I will mention here the remainder of the necessary instruments. The method of their use and their relative importance is detailed in the pages referred to in brackets. The order of enumeration in no way indicates their degree of usefulness.

One very delicate forceps, 17-18 centimetres long, without end-pieces, for children.
Endoscopic telescope (see pp. 36 and 37).
Prism with double eye-piece for two observers (see p. 37).
A dilating extractor for foreign bodies embedded in the gullet (see p. 295).
A dilating extractor for foreign bodies behind bronchial stenoses.
Concentric metal bougies for broncho-intubation.
Tracheograph bronchometer (see pp. 207 and 210).
Counter-pressure autoscope for endolaryngeal operations under general anæsthesia, and special operation instruments.
Dynamometric dilator for cardiac end of stomach and upper end of gullet.
Special instruments for endoscopy in children (electroscope for children).
Tracheal funnel.
Forceps for children.
Autoscope for direct autoscopy of the larynx.
Operating instruments with special objects.
Forceps.
Loop extractor.
Collar-stud forceps.
Medicament applicator.

A complete instrumental outfit, in its widest sense, would include certain additional instruments, which are, however, for the most part necessary only in the operating theatre of a clinic. The degree of equipment is, of course, a matter of cost. For slender purses and for outside work the instruments contained in my instrumentarium will suffice. I except, of course, the source of current, and I would also strongly advise the inclusion of a tracheotomy set, an accessory which is most strongly to be recommended in every case. An apparatus for the administration of oxygen and for oxygen-chloroform anæsthesia is also desirable. This matter will, however, be further referred to on p. 80 *et seq.*

In addition to the above, the consideration of a special room for direct examinations should be mentioned. Such a room should be fairly dark—in fact, only light enough for the operator to distinguish the instruments and obtain an adequate appreciation of the patient's face.

For more accurate observation and the use of the telescopic attachment almost complete darkness is desirable. The source of light, whether lamp or window, should always be behind the surgeon, so that he shields the tube from it, with the result that the brightness of the image is intensified by contrast.

It is important, when currents of certain strengths are used (a matter which will be referred to in the next section), that the flooring on which the surgeon stands should be made of dry wood, xylolith, or some similar material. If the floor is a stone one, it is advisable, both for the patient and the surgeon, to cover it with linoleum.

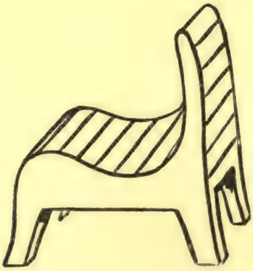

FIG. 2.—ENDOSCOPY STOOL. (After Brünings.)

Observations and operations on a patient in the upright position are best conducted on a low stool about 35 centimetres from the floor. I have had a special "endoscopy stool" constructed for the purpose. It is designed to hold the patient in the position which is most favourable for the examination (Fig. 2).

If I were considering the construction of a special table, it would, I think, be advisable to lay stress on the following particulars:

1. As regards material. Owing to the possibility of electric shocks through contact with the ground, wood is preferable—

at least for the table-top. Metal tables should be placed on glass feet such as are used for pianos. 2. The table must be of a considerable height so that the surgeon can easily see down the tube from the sitting position. 3. It is very necessary to have some mechanism by which the head end of the table can be lowered; as a rule, the axis of movement lies in the middle, so that advantage can be taken of the weight of the body. It would, however, be better if the movable point were located more under the shoulders and only the feet end of the body moved, as otherwise the head of the patient is apt to be so far lowered that it is only by sitting on the floor that the surgeon can carry out the necessary manipulations. In every case a table of sufficient height should be chosen in the first instance, unless one with the complex apparatus for alteration of height is contemplated. I know of no table specially designed for examinations by the direct method, but such a one could easily be constructed in accordance with the various points just enumerated.

As a necessary part of the endoscopic outfit I must add an instrument sterilizer at least 36 centimetres long. For warming the mirror of the electroscope and the instruments before introducing them, the ordinary Argand examination lamp (with light-tight shield) will suffice. In cases where electric light is used, a spirit-lamp or heated instrument table will be necessary.

Dipping the instruments in warm water entails too much loss of time, as the drops of water which adhere must in every case be removed from the tubes.

In many cases—*e.g.*, severe bronchitis, hæmorrhage, œsophageal dilatation, overloaded stomach—a continual cleansing of the field of vision is indispensable, and for this the small saliva hand-pump is not always powerful enough. A more powerful action is obtained if the syringe is fitted to a large suction-tube with side-holes. The working of this, however, requires two hands.

In these cases I strongly recommend the use of water-jet suction-pumps, as by far the most practical and convenient, if the requisite water-pressure (of at least two atmospheres) is readily available. A pump with a construction such as the following one seems to me the simplest. The water-pump A* (Fig. 3) is attached by a moderately thick rubber tube to the ordinary main tap, or else to a special side tap if the main tap is required for other purposes.

Another tube connects the pump with a 5 - 10 litre flask B, which is fitted with a doubly-pierced rubber cork.

With this flask a long thick-walled rubber tube communicates,

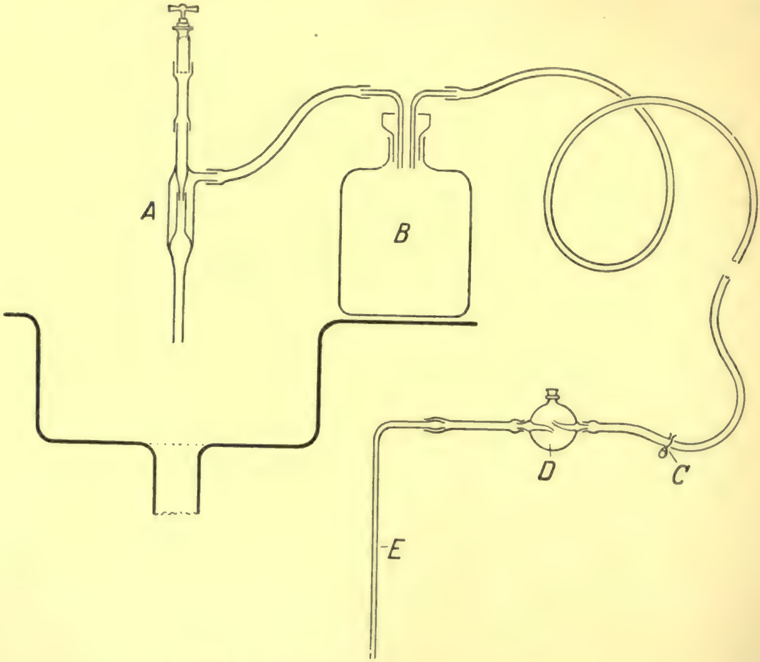

FIG. 3.—WATER-JET SUCTION-PUMP.

and this leads to the pump-tube E, a round glass vessel D (as in the small saliva pump) being interposed.

The clip C, shown in the figure, can usually be dispensed with.

In my present clinic I have so arranged the apparatus that the flask B, which is necessarily near the water-supply, is connected to the light bracket above my operating-table by a piece of gas-piping. From the bracket hangs a short rubber tube, which connects with the pump-tube and interposed reservoir.

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* An ordinary cheap glass pump, such as is sold in the shops for one or two shillings, is quite adequate. The whole outfit can, however, be obtained from Fischer of Freiburg.

I have found this arrangement very convenient and durable, and, in view of the importance of keeping the field of vision properly clean, I would strongly advocate its adoption in places where examinations are likely to be conducted in the ordinary routine.

Sources of Electric Current.

It is impossible to answer in a general way the question, which is so often asked, as to which is the best source of supply of electric current. At any rate, it is unanswerable without a previous knowledge of the uses to which the current is to be put, and the possibilities which there may be of using a town main supply. Even with this knowledge, the varying demands which are made for economy, safety, and convenience, leave such a large margin for the employment of many kinds of sources, that a surgeon with but small experience is placed in an awkward position when he has to choose between the advertised apparatus of many firms, especially since there does not, to my knowledge, exist any kind of elementary treatise on this subject.

I will therefore treat this subject firstly by enumerating the various sources of current, together with the advantages and disadvantages of each, and secondly by giving a tabular summary of the kinds of source necessary for various purposes.

The carbon filament lamp of my electroscope burns at an E.M.F. of 10 to 14 volts. Hence the current must permit of being regulated within this limit, and in steps of not more than 0·5 volt at a time. For this purpose the sources of current generally used for surgical lamps can be used, viz.:

A. Primary batteries.
B. Secondary batteries (accumulators).
C. Switchboards which are connected straight to town mains.

A. *Primary batteries* are a kind of emergency help, and are used only for travelling purposes, and when every other kind of electric supply is lacking. If any demands are made for immediate readiness for use and cleanliness, only the so-called "dry cells" can be recommended. They have an E.M.F. of 1·5 to 1·0 volt, and consequently at least 10 or 12 cells must be used in series. They must be fairly large on account of the inconstancy of the E.M.F., and, for the same reason, a wire resistance is necessary.

Dry cells, as compared with accumulators, have the advantage of being very much lighter, and so more suitable for transport. But their disadvantages are—1. Expense, because the exhausted cells cannot be used again. 2. They have only a small capacity, and their E.M.F. is not constant, both of which facts render a long demand for current impossible. 3. They tend to discharge even when not in use, so that a battery is discharged in less than a year whether it has been used or not.

Batteries made according to these instructions are supplied by K. Schall, London, at prices ranging from £2 10s. to £4, but I repeat that they only constitute an emergency help for travelling.

B. *The secondary batteries* (lead accumulators) form the best source of current for consulting-rooms in which no main current is available. At the same time access must be possible to a main supply, which must be continuous (not alternating or three-phase), for the purpose of charging the cells. It is an expensive proceeding to charge them by means of thermopiles or small dynamos.

Accumulators can be used with advantage even in those consulting-rooms where the main current *is* available—because (1) the current which they supply is not dangerous; (2) they can be transported independently of the main supply; (3) they work noiselessly. Their disadvantages are—(1) They are expensive on account of the uneconomical way in which they have to be charged, and this soon makes up for their cheapness when they are first bought; (2) they have to be treated carefully, the voltage must be tested periodically, they must be charged at proper intervals, and the acid has to be renewed from time to time; (3) their life is rather short, being something over five years when they are properly looked after.

After having weighed the advantages and disadvantages carefully against each other, I recommend the use of accumulators in the following cases:

1. For surgeons who possess no direct connection to the main, but have the possibility of charging the cells in the neighbourhood.

2. For surgeons who, beside using the current in their consulting-rooms, sometimes require it for outside work.

3. The use of accumulators is preferable when the main continuous current is over 110 volts or when a three-wire system is used, and when the acquisition of a motor converter for such current entails too much expense (*i.e.*, about £10), or the noise of such a machine is too great. Rheostats off the main are often dangerous for surgical lamps.

Accumulators are not useful to surgeons who require the current irregularly and seldom, because their E.M.F. drops when not in use, and they become discharged after one or two months.

For the present purposes accumulators must have not less than eight cells in series, and must be supplied with a controlling resistance. The size of plates must permit of a discharging current of at least 1 ampère. Space prevents my treating here of the care and management of accumulators.

C. *The apparatus which are attached straight to the main* have driven the accumulators and dry cells away from consulting-rooms since the main current has become more and more available. Their advantages are indeed very great, but, in order that the best use may be made of these advantages, the instruments must be properly and exactly suited to the varying kinds of supply current, and to the purposes for which they are required.

In the present case these main supply instruments have to make the high-tension current from the power-station suitable for small surgical lamps by reducing its voltage. They can be divided into three classes: (*a*) Rheostats, (*b*) stationary transformers, (*c*) motor converters.

RHEOSTATS.

These are constructed on two different principles—either they reduce the current, the lamp being then placed in series with the main, or else they reduce the voltage and then the lamp is placed in shunt.

The plan of the first kind of connection is shown in Fig. 4, I. The main current enters the rheostat at *a*, flows through the piece *ab*, and is thereby so reduced in strength that it is just sufficient to light the lamp *g*. The length of the resistance *ab* is varied by means of the sliding contact *c*, so that a very accurate regulation is possible.

The series rheostats are, for many reasons, not very suitable for main currents. Two reasons are that, in consequence of the lamp being worked straight off the undiminished main voltage, considerable sparks take place when the switch is being opened, and that if they are touched a shock may be experienced.

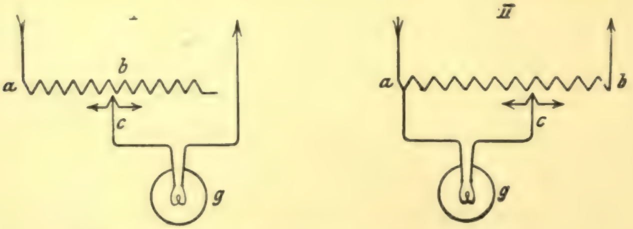


FIG. 4.—SERIES RHEOSTAT; SHUNT RHEOSTAT.

The shunt rheostats are very much better suited to the requirements. A current flows continually through the constant resistance *ab* (Fig. 4, II.), so that there is a uniform drop of potential all along the resistance, the drop depending on the size of the resistance. By putting the lamp *g* in shunt between *a* and the sliding contact *c*, a certain quantity of this voltage is branched off through it, and this can be varied by moving *c*. When the lamp is reversed or switched off, the rheostat is not interrupted and the current flows on; consequently, this kind of apparatus must be disconnected from the main immediately after use.

Many of the cheap rheostats on the market are made for too weak a current. They must be tested to show (1) whether the current is sufficient for an old and worn-out lamp, and (2) whether the rheostat becomes hot after fifteen minutes' use, which should not be the case to an excessive degree.

The material of which resistances to be used with the main current are made should be metal wire (rheotan or German silver) or carbon used in the form of lamps. The sliding contact is generally moved by means of a wheel and ratchet, or a screw thread in the case of good instruments, because the ordinary contacts move too unevenly and sometimes cause a lamp to be burnt out.

The advantages of the rheostats are—(1) Cheapness (£1 10s. to £3 10s.); they are compact and easy to handle. (2) They are adaptable over a wide range, as they can be worked off continuous, alternating, and three-phase currents at the same voltage. The lamp resistances, in fact, can be adapted to any voltage by merely changing the lamps in circuit, and can, consequently, be used by a surgeon when working in patients' houses where the current is laid on.

Unfortunately, all these apparatus have the one principal disadvantage, that they work from the main voltage, and so the danger of shocks cannot be absolutely excluded even in the shunt circuit. This fact is very important, because a current at 110 volts applied to the mucous membrane of either the windpipe or the œsophagus produces instantaneous death.

Accidents due to shock are produced in the case of well-conducted instruments only through the patient being "earthed"—*i.e.*, that either he or the surgeon comes into contact with one pole of the electric circuit while at the same time coming into conducting connection with the earth. The latter condition most readily occurs through the touching of gas or water pipes. For higher main voltages it is sufficient to stand on a wet stone floor to get a shock. Safety in this direction is more or less guaranteed if the surgeon stands on dry india-rubber or linoleum, but for a three-wire system even this may not be sufficient.

This being connected to earth becomes dangerous in inverse proportion to the success with which the power-station plant is insulated from earth. No power-station has perfect insulation, but surgeons can work with rheostats on a 110-volt circuit if they employ the precautions outlined above. A 220-volt circuit should only be employed with the greatest care, and by working on a greased wooden floor. Higher voltages—*e.g.*, 440 volts—are generally split into two 220-volt circuits by a light conductor, which is earthed, running between the two insulated ones, and producing one of the last-named circuits with each. There is one such plant in Freiburg, and I consider the use of a rheostat on it as absolutely unjustifiable.

For these reasons the rheostat will, unfortunately, always remain but an imperfect apparatus, particularly since modern power-stations are inclining more and more to high-tension three-wire circuits.

TRANSFORMERS.

Stationary transformers as well as motor converters depend for their action on electric induction—*i.e.*, on the fact that the variations of current in a "primary" coil produce variations of current in the opposite direction in a neighbouring "secondary" coil. The voltage of this secondary current can be made of any desired value by using suitable relative numbers of turns of wire in the two coils. Hence the voltage of a power-station supply can be transformed down so as to be a current absolutely independent of this supply, and similar to one obtained from galvanic cells.

For the purpose in hand two kinds of transformers have to be dealt with, according to whether the main supply current is continuous or alternating, either single-phase or three-phase. In the case of continuous current, the variations necessary to a primary current before it can be transformed are imposed on it by some kind of interrupter—*e.g.*, "Wagner's Hammer." Such arrangements are not, however, very useful for surgical lamp work, because the interrupter often works too slowly, and consequently the lamps flicker and are soon worn out. In addition, the interrupter makes rather a noise.

Consequently, transformers are best adapted to single-phase or three-phase alternating current, and with these they render excellent services. Modern power-stations supply almost without exception one of the above-mentioned currents, and so stationary transformers will become by far the most perfect of all instruments which can be attached to the main. Their advantages are—1. Complete absence of danger. 2. They require no attention whatever. 3. They work noiselessly, are transportable, and can, if properly constructed, be run off any voltage between 110 and 220. 4. By putting another secondary winding on the same primary, it is possible to obtain a cautery current independen of that going through the lamp. 5. They are cheap (£5 to £9, according to whether the additional cautery current is required or not).

Only large accumulator batteries can supply both light and cautery currents, and this fact, which a surgeon does not like to sacrifice, renders stationary transformers preferable to any other instrument, provided that the alternating current is available.

Useful transformers are supplied by most electro-medical firms, but the mountings are often inconvenient and unaseptic. A good pattern, which is free from these disadvantages, is that made by K. Schall, London.

MOTOR CONVERTERS.

The motor converters also transform the high-tension current to a lower voltage, and their principle differs from that of the stationary transformers in that a number of turns of wire wound on an armature are pulled past one or more fixed coils of wire through which a continuous current flows. The alternating current which is induced in the moving turns of wire is taken off the armature by means of slip-rings, and, as it still has about half the tension of the original continuous current, it is passed through a stationary transformer to be brought down to the required voltage. Hence the motor converter really only serves the purpose of changing the continuous current to an alternating one before it is transformed in the way indicated in the last paragraph.

As far as the quality of the current is concerned, the motor converter does exactly the same as the stationary transformer. Its disadvantages compared with the latter are—1. It runs more or less noisily. 2. It is heavier and more expensive, particularly when cautery current is required as well as current for light. 3. There is the possibility of a breakdown in consequence of wear and tear.

In spite of these disadvantages I recommend a motor converter for all continuous currents of more than 110 volts—wherever an accumulator is not preferable on account of its transportability. At the same time a motor converter can be so arranged that it will run off continuous and single- or three-phase alternating currents. The current in the last two cases is not led through the motor at all, but straight into the transformer.

While dealing with apparatus which can be attached straight to the main, mention also must be made of—

Universal Apparatus,

which are to-day to be found in all shapes and forms on the market. There is a more or less happy combination of rheostats, transformers, and converters, to give all the currents required. Frequently the efficiency of the individual current suffers. I can deal in the case of these complicated and expensive apparatus only with the best products—*e.g.*, the "Pantostat" (made by K. Schall, London) or the "Multostat" (made by the Sanitas Company). Whether a universal apparatus is acquired or not depends on the extent to which it is put to its various uses—galvanization, electrolysis, cataphoresis, sinusoidal faradization—because it is obvious that the principal product, namely, current for surgical lamps and perhaps the additional current for galvanic cautery, can be supplied at least as well by apparatus constructed solely for the purpose.

From the above remarks, it becomes obvious that the question as to the source of current is still very complicated, partly on account of the quantitative and qualitative differences in the currents supplied by power-stations, and, again, on account of the very wide range of currents necessary for electro-medical purposes. For instance, two extremes are—continuous current of 150 volts, with immunity from earth connection for galvanic work, and cautery current for twenty or more ampères.

If in a town both continuous and alternating currents are available, the latter is far preferable for this particular purpose, on account of its easy transformability. If, however, X-ray work, galvanization, and electrolysis, are required at the same time, the continuous current must be chosen.

For hospitals it is a good plan to have a large transformer or motor converter in a cellar, to supply a low-tension current of about 25 volts to the various theatres and laboratories. This current can then be used with the help of rheostats. Such a low-tension plant is not very expensive, and has the advantage of being harmless, simple, and noiseless.

A table of apparatus to be used under various conditions, together with the approximate prices, is given below.

SUPPLY CURRENT.	APPARATUS NECESSARY.
1. No main current and no possibility of charging accumulators.	Dry cell battery (£2 10s. to £4).
2. No main current, but a possibility of charging accumulators.	Accumulator battery of eight cells (£4 10s., £6, or £6 10s., £7 10s., if cautery currents also required).
3. Continuous current (65 to 110 volts).	Rheostat (£1 10s., £3 10s.) to be used with linoleum if there is a concrete floor. For simultaneous cautery and light work, transformer with hammer interrupter (£10, £11).
4. Two-wire continuous current (220 volts).	On wood floor, rheostat (£3 to £4); on stone floor, rheostat and linoleum, or, rather, a motor converter (£9 to £10, and £15 to £17 for simultaneous cautery) or accumulators.
5. Three-wire continuous current (220 volts or more).	Motor converter (£9 to £10, and £15 to £17 for simultaneous cautery) or accumulators.

SUPPLY CURRENT.	APPARATUS NECESSARY.
6. Alternating current up to 110 volts.	Rheostat (£2 to £3 10s.) with linoleum for concreted floor, or, rather, and useful for cautery also, transformer (£8 to £9).
7. Two-wire alternating current to 220 volts.	On wood floor, rheostat (£3 to £4); on stone floor, rheostat with linoleum, or, rather, and useful also for cautery, transformer (£8 to £9).
8. Three-wire alternating current of 220 volts and more.	Transformer for cautery and light (£8 to £9).
9. Three-phase current of 220 volts and more.	Transformer for cautery and light (£8 to £9).
10. Cases 3 to 9, if galvanization, electrolysis, cataphoresis, and sinusoidal faradization are required.	Universal apparatus (£23 to £30).

I should mention that the above statements only hold good for carbon filament burners. Other considerations must be taken into account for metallic filament lamps, the use of which, however, I do not recommend—at any rate, as they are at present manufactured.

The metallic filament must be short and thick if it is to attain the same light intensity per unit of length as the carbon filament. Its resistance falls, therefore, so that a current of 3 to 6 ampères (as against ½ to 1 ampère for the carbon filament) is necessary. The majority of transformers, and almost all rheostats, cannot provide this current; it is therefore advisable to be satisfied on this point before purchasing one, if it is desired to use metallic filament burners.

With old carbon filament burners the current is apt to produce an intense white glow, and this must be guarded against.

It should be noted that metallic filament burners have the great advantage that, when the surgeon is away from home, they can be readily worked by a small portable one- or two-celled accumulator. This is a great recommendation, even though the light may not be so good.

The overheating of the mirror can be minimized by the use of soap solution or other means.

When an installation for endoscopic purposes is being made, the possibility of the simultaneous use of the cautery should always be taken into account, since deep galvano-caustic puncture in laryngeal tuberculosis is carried out much more easily by means of counter-pressure autoscopy than by the indirect method.

Many of the apparatus on the market, which allow simultaneous use of the light and cautery, suffer from the disadvantage that there is a marked falling off in the intensity of the light when the cautery is working. Attention should be paid to this point when making a choice.

II. GENERAL MANIPULATION OF THE INSTRUMENTS.

When the various pieces of endoscopic apparatus were enumerated, no attention was devoted to their manipulation, so that I propose to discuss briefly the practical details in the use of the three chief instruments—electroscope, tube apparatus, and forceps —as in a way the successful use of the instrument is closely dependent on the action of their component parts.

Management of the Electroscope.

The electroscope is usually sent from the instrument-makers' with the reflector in such a position as to enable it to travel safely.

The reflector is turned round the axis *cd* (Fig. 5) through an angle of 90°, so that the screw *h* lies between the arms of the tube-carrier *r*. It is protected from damage in this position, and the instrument can lie flat.

Before use the screw *h* must be loosened, and the reflector twisted into its normal postion.

1. The Regulation of Light Strength.

Turn the indicator of the (as yet unknown) current-meter to "Weak"; the same source of current is regularly used. A mark can be made to indicate the usual position of the rheostat, but it must always be borne in mind that the requisite strength of current varies for different lamps, and indeed for similar lamps when they have been used for varying times, and also that in accumulators the charge varies somewhat (between 2·2 and 1·8 volts per cell).

With an unknown strength of current and especially with one which is possibly excessive, it is advisable first to open the key *o* and then place the wire terminals in the slot *p*.

The key *o* can then be closed for a moment as a trial; and even if the current is too strong, there is some protection against the possibility of the lamp fusing, and it is possible to adjust the regulator more accurately. For technical adjustment of the light intensity, the mirror-piece should be raised, and the condenser removed before increasing the strength of current.

It is, naturally, not possible to lay down an exact measure for the right degree of illumination, but the following rules may serve a useful purpose.

If the three-wired burner is examined when the condenser is removed, the wires first begin to glow, and then to light up as the current is increased, so that the light appears more diffused. The correct intensity is obtained when the star-like form of the burner is no longer sharply defined.

A further indication is given by the colour of the pencil of light when thrown on to a white surface 10 to 20 centimetres from the condenser.

The hexagonal middle field appears almost white. This occurs if the individual wires, which project beyond the middle field, still have the yellow colour of the ordinary single-wired burner. In such an estimation as this, the fact that the spot of light appears whiter in proportion to its nearness to the white surface, and to the smallness of the field, must naturally be taken into consideration.

With a little practice, the proper intensity can readily be estimated by the colour of the light spot projected on to the hand.

A sudden fusing of the lamp is not so likely to occur if care is

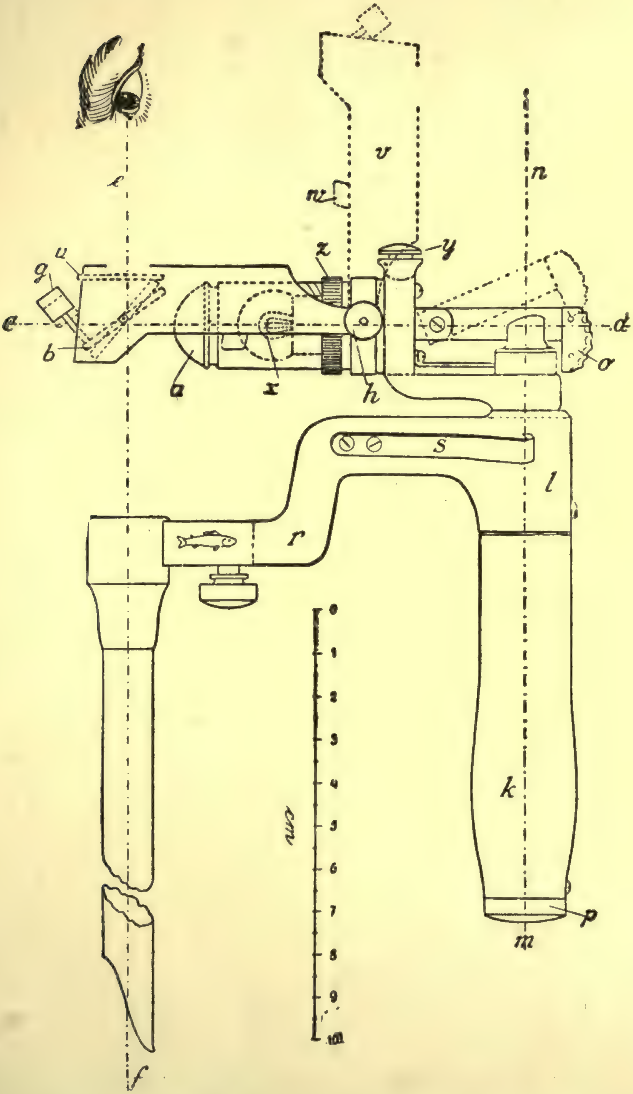


FIG. 5.—SPECIAL ELECTROSCOPE FOR BRONCHOSCOPY. (After Brünings.)

taken to preserve it from overstrain. The following rules are useful in this connection:

1. The key should only be closed during the actual period of observation.
2. The strength of light should be adapted to the needs of different cases; thus, for autoscopy an illumination is required about five times less than that necessary for bronchoscopy with a narrow soiled tube, or for telescopic observation.

2. PROJECTION OF THE LIGHT IN THE TUBE.

When the requisite tube spatula (without inner tube) has been fitted into the electroscope, the mirror-holder is lowered and the instrument placed with the oblique end of the spatula against a white background, or held a short distance from a light wall.

The image of the cross-wires will appear more or less excentric to the end of the tube.

The centring of the light is produced as follows: After loosening the screw *h*, the mirror-carrier is rotated about the axis *cd* until the spot of light falls parallel with the axis of the tube; the screw *g*, which moves the mirror in a sagittal direction, is then manipulated until the light rays are centred in this plane also. A correct adjustment is attained when the ends of the pattern which project beyond the tube do so equally on all sides.

This important matter of centring the light should be done before every endoscopic examination; it takes no more time than the adjustment of the reflecting mirror of a microscope.

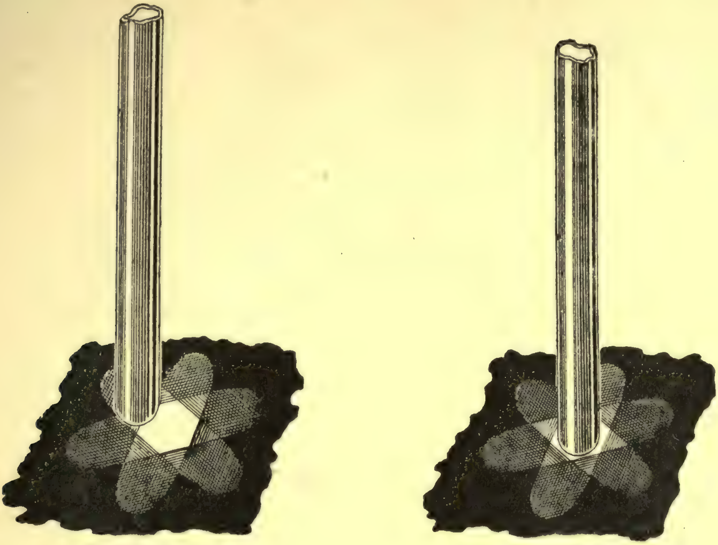
3. THE ADJUSTMENT OF THE CONDENSER

has for its object the adaptation of the cross-section of the hexagonal pencil of light (Fig. 6) to the cross-section of the tube which is to be used.

The end of the tube is held obliquely against the white background, so that observation can be made from the side from which the circle of light is cast, and the ring *z* of the condenser is then twisted until the light circle attains the maximum brilliancy.

It is profitable to practise this trial focussing with lengths of tube which will in some measure correspond with those to be employed later.

The three essentials of light adjustment which I have detailed are as easily put into practice as described. For the most part, one or other will appear profoundly unnecessary; but nevertheless I should recommend, even though only for purposes of control, that the sequence of procedure should be followed pedantically, as thereby proficiency will most quickly be attained.



Wrong. Right.

Fig. 6.—Centring of the Light.

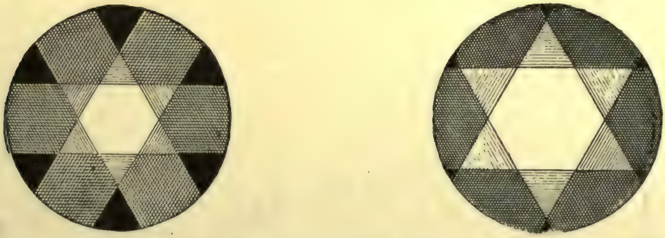


Fig. 7.—Image of Light with Different Positions of the Condenser.

In conclusion I will review the most frequent causes of failure in the management of the light, and how they may be rectified.

I. Total failure of the light. First examine the three chief points of contact: the connection with the main, the connection of the cords leading to the electroscope with the source of the electric supply, and the contact with the incandescent lamp. Any loose contact, especially between the incandescent lamp and its socket, will cause a flickering of the light.

If these contacts are in order, ascertain whether the filament of the incandescent lamp has been burned out by replacing it by a new lamp (use a weak current only).

If there is no defect in the lamp, it is then necessary to examine the whole circuit. In this there are three weak points: the fuse of the main, and the two connecting cords. First test whether there is any current—(1) by turning on an ordinary lamp for lighting the room; (2) by testing whether any current can be obtained from the poles of the apparatus or the accumulators; (3) by testing whether there is a current at the poles of the cable or the plug leading to the apparatus. (It is very unlikely that any defect will occur in the electroscope itself.)

Most frequently the fault mentioned under (1) will occur if the lamp is not screwed home, or if there is a defect in the cords. In the latter case the light flickers if the cords are moved whilst the instrument is held quite firmly. If there is any defect, it is a mistake to try and correct it by increasing the strength of the current.*

II. If the lamp is working well, and a good illumination in the tube is still not obtained, it is probable that either the condenser or mirror is dirty, or else the mirror is improperly adjusted. These things are easily remedied, but it must always be remembered that the mirror must be warmed before the tube is introduced. This is best effected by means of a spirit-lamp, or by turning on the light of the electroscope for a minute or two.

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* To test for current, information may be obtained from—(1) A small pocket voltmeter for 0 to 16 volts, as used for testing accumulators. (2) The appearance of sparks may be looked for by interrupting the current. These are only visible with currents of 10 volts or more, or by rubbing with a wire on a rough surface, such as a file. (3) A commercial pole-finding paper. (4) A piece of white bread soaked in a solution of iodide of potassium, which leaves a red stain on the negative pole. (3) and (4) can be used only on a continuous current. (5) If the current does not exceed 12 volts (with accumulators or primary batteries, transformers, etc.), the test of touching both poles with the tongue may be applied.

III. If there is a sudden decrease in the strength of the light during the examination, the current should not be automatically increased, but an effort should be made to find out whether the mirror-holder is properly in position, or whether the mirror is covered with expectoration, or whether the interior of the tube is soiled by blood or secretion.

Only when the light fails entirely can this be attributed to deficiency of the current or the burner being worn out, and the current may be increased in strength.

IV. I must not omit to call attention to another important source of failure. It often happens that the rings, as seen through the tube, appear blurred. If the eye is gradually withdrawn from the slot in the mirror, it will be seen that the reason of this is to be found in reflections from the bright edges of the slot in the mirror. These should be blackened with paint or ink.

The beginner is particularly exhorted to investigate any failures under these four headings. An accurate statement of the possibilities of error should, at any rate, prevent the surgeon from reflexly increasing the current until the lamp fuses whenever he fails to see clearly.

In discussing the management of the electroscope, I must refer to the use of the endoscopic telescope and double prism.

It is advisable to consider the question of these when the electroscope is being chosen, since the knob *Y* and the disc *U* (Fig. 5) are essential for their use and are sometimes omitted.

If it is desired to use one of these instruments during the course of the examination, the glass disc *U* must first of all be inserted. If it has not been previously warmed, a minute must be allowed to elapse until the expired air no longer condenses on the glass. If the image should still appear indistinct, it is probable that the slit in the disc is blocked up, so that it must either be thoroughly cleaned or pushed directly over the slot in the mirror.

In œsophagoscopy these difficulties are often met with, and the protecting disc may be quite useless.

The method of holding and introducing the electroscope will be fully dealt with in the succeeding chapters.

Now that a general review of the composition of the endoscopic instrumentarium has been given, it is well to consider at this point the

Construction and Management of the Chief Instruments.

By this I mean the lighting apparatus, the endoscopic tubes, and the operating instruments. I will arrange the matter so that the description will at the same time afford a criticism of the instruments in question.

THE LIGHTING APPARATUS.

I think that the extreme importance of this part of the endoscopic equipment justifies me in devoting a few words to the principles which underlie the construction of different kinds of lamps.

Internal or External Lamp?

The endoscopic illumination of cavities in the body can be undertaken on two different principles.* A small lamp may be fastened near the distal end of the endoscopic tube (internal lamp), or the lamp may be fixed outside the tube near its proximal end.

A theoretical analysis of the question of illumination shows that inside lamps are best adapted to "cystoscopic" purposes, by which is meant the inspection of globular cavities. These require a diffuse illumination of extensive surfaces situated perpendicularly to the line of sight. On the other hand, "syringoscopy"—that is to say, the inspection of tubular cavities (œsophagus, bronchial tree, etc.)—requires a light of great penetrative power, in order that the various points of the organ, situated at different distances in the line of sight, may be illuminated as equally as possible. This is necessary for the accurate orientation of the bronchial tree, and this is considerably facilitated when it is possible simultaneously to see extensive tracts with their various lateral branches. It has, moreover, to be remembered that, in many stenoses and in the finer bronchi in which the tube itself cannot be introduced, it is only possible to see by means of a projected light, and this must be of great penetrative power.

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* A full account of the theory of endoscopic illumination will be found in the German edition of this book, and also in an article by Brünings, "Über die Beleuchtungs Prinzipien endoskopischer Rohre" (*Verh. d. Vereins Süddeutscher Laryngologen*, Würzburg, 1906).

The theory of endoscopic illumination shows that all open inside lamps are capable only of very small penetration, their light decreasing in proportion to the square of the distance. Consequently, that portion of the tubular organ which is in the immediate neighbourhood of the burner will be brilliantly illuminated, whereas a few centimetres beyond there will be relative darkness. If, on the other hand, the light of a bright outside lamp is projected into the tube, this drawback disappears, and its disappearance is successful in proportion to the extent to which the rays have been previously parallelized, which is easily effected by employing lenses; for parallelized light possesses a constant brightness which is nearly independent of distance.

There can, therefore, be no doubt theoretically that a parallel-radiating outside lamp is superior in respect of penetration to any kind of inside lamp. It also offers various advantages in practice, for inside lamps in all cases conceal a large portion of the field of vision, which in the case of narrow tubes amounts to more than one half. Moreover, the great fragility of inside lamps renders them dangerous, and they are soiled by the slightest traces of secretion, and must therefore be constantly changed in the course of an operation. Moreover, they cannot be employed with my double extensible tubes, and that for mechanical reasons.

It will be understood from these remarks that, differing from many authors (Jackson and others), I give the preference to the outside lamp with condensed light. There is, however, another question to decide before constructing the instrument, viz., What form should it have—that of a

Frontal Lamp or Electroscope?

Both contrivances aim at the same ideal—the "illuminating eye." With the electroscope this eye is presented and kept in position mechanically, whereas with the frontal lamp this has to be effected through the attention and muscular movements of the operator. If it is remembered, too, that the discoveries made with the electroscope can be demonstrated to others, can be magnified and inspected stereoscopically, there is considerable inclination to give this instrument the absolute preference for all cases. But, as I shall immediately show, this is not correct, and I have added an electroscope to my set of instruments only because experience shows that the great majority of investigators obtain the best results, in the general run of cases, with this apparatus. I know this, not only from large experience in demonstrating and from numerous verbal and written communications of recent date, but also from recent publications in which certain well-known bronchoscopists, who had previously worked with the frontal lamp, point out the advantages of the electroscope.

I should not lay so much stress on this point did I not know that experienced bronchoscopists are still using the frontal lamp. No doubt it is possible, with sufficient practice, to obtain excellent results with this instrument, but in order to attain and maintain such dexterity it is necessary to be able to command extensive endoscopic material. The beginner has to cope at the same time with all the various difficulties, because the direct method cannot be acquired by degrees, as can skill with the laryngoscopic mirror, but either gives a complete result or nothing at all. It is therefore the more important that the first attempts should be made with an instrument with which the light is not liable to fail, and with which the surgeon can work steadily while relying on an equable automatic illumination.

It seems to me that the superiority of the electroscope as compared with the frontal lamp admits of no doubt. The only question remaining is, how far the automatic illuminating apparatus can be so adapted for operations as to enable the operator to use his instrument as freely as when he employs a frontal lamp. With none of the electroscopes hitherto used has this been attained, or even aimed at, and it seems to me that this essential disadvantage, rather than the bad light, accounts for the fact that most surgeons have put up with more or less imperfect lamps. As will be seen in the next section, it is quite possible to construct an electroscope for operations in such a way as to admit of the free use of all the instruments while taking full advantage of the light. No doubt it is necessary to acquire certain tricks in the use of the electroscope and forceps. Whoever prefers to shirk the trouble of acquiring this knack must do his best with the frontal lamp. This certainly also has its own advantages in certain cases, as mentioned above, especially when examining patients with much expectoration, and when dealing with young children under certain circumstances.

THE BRONCHO-ELECTROSCOPE.

In constructing an electroscope it is necessary, as has been explained above, to combine in the best possible manner two separate objects —*i.e.*, the best illumination and a mechanism which permits of light being used even during the operation. Both these objects must mutually limit and depend on one another. Bronchoscopy in particular makes the greatest demands on the electroscope, both as regards illuminating power and its mechanical properties. A certain degree of complication of the special electroscope for bronchoscopy which is described below is therefore unavoidable in order to obtain good results. The instrument is consequently heavier and more expensive, but its use is very simple, and it works so well that I have not yet noticed the slightest deterioration in the one I use.

Of the two main parts of the electroscope—the illuminating apparatus and the mechanical part—I shall begin with the first. This consists of the burner, condenser, and reflector.

After many trials, I have constructed a burner which is a three-filament carbon-lamp (Fig. 8), from which parallel-rayed light can best be projected. By placing in front a collecting-lens, images of the forms indicated (Fig. 7) can be obtained according to the distance of the lens. The three-thread images cross each other in a central hexagon, which consists of parallel light of threefold brightness.

As the burner has not only to illuminate, but at the same time to warm the electroscopic mirror, the "cold" metal filament lamps are less adapted to the purpose in hand. They can be obtained, if specially asked for, from the instrument-maker* in the same form as the carbon lamps.

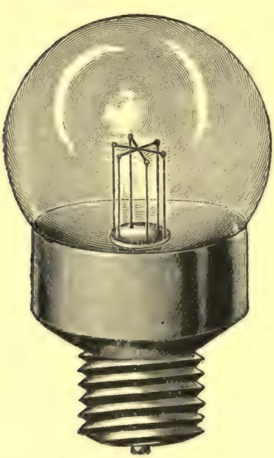

Fig. 8.—Three-Filament Projection Burner. (After Brünings.)

They have the advantage of being carried easily, together with the requisite accumulator, when operations away from home are necessary, because they will burn with a tension of 4 volts only, whereas the carbon lamp requires from 10 to 12 volts, according to its newness.

In Fig. 5, showing the construction, the situation of the burner is indicated by *x*. The current is brought from the box *p* and through the handle *k*, and can be interrupted by means of the switch *o*.

The collecting-lens *a* (Fig. 5) serves as a condenser. Its function is to parallelize as much of the light as possible, and this is best effected by means of a plane-parabola lens with a refraction of 40 to 50 diopters. Experiment has shown that nothing is gained for the particular purpose by substituting several separate lenses.

The condenser can be moved nearer to, or farther from, the source of light by turning a screw, *z*, producing a change in the

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[*] All the instruments described in this book are constructed only by F. L. Fischer, of Freiburg im Breisgau. Imitations and modifications, especially those by Austrian firms, have proved less satisfactory.

diameter of the hexagonal field of light (Fig. 7). The use of this contrivance is described farther on.

The reflector, which has to project the parallelized light into the tube, consists of a plane-mirror (*b*, Fig. 5), which is adjusted in the mirror-holder in such a way that it can be inclined in two opposite planes, and therefore in all directions.

This manipulation is effected by means of two screws—viz., screw *g*,* the effect of which is indicated by the dotted position of the mirror, and screw-head *h*, by loosening which the entire mirror-holder can be turned round the axis *cd*. The revolution of the mirror takes place exactly about its centre, the eyehole of the mirror remaining in the axis of the tube.

This manipulation of the reflector is essentially important, because only in this way can the crossing-point of the star-burner be accurately adjusted to the end of the tube, and the rays consequently be projected exactly in the same axis as the tube. The mechanism by which the mirror is moved is so contrived that a spring will press it back automatically into position, if it has been moved, say, for the purpose of cleaning. It should also be mentioned that the conical funnels of all tubes used in the electroscope are of the same form and size, so that every tube, on being placed in the holder *r*, will be centred automatically on the mirror.

I now come to the mechanical arrangements of the electroscope, which also includes the form of the handle. This handle, in distinction from all other electroscopes, is placed parallel to the tube, and thus in bronchoscopy a natural position of the hand and a more effective manipulation in any direction are rendered possible. This is described elsewhere in greater detail.†

As the instrument was intended to be a complete substitute for the frontal lamp, special contrivances had to be devised which should imitate, as well as possible, the advantages of the frontal lamp in operations. These advantages obviously consist in the fact that on introducing instruments it can be quickly moved aside without the hands being used, and that, after the introduction of the instrument, the distance between the frontal lamp and the end of the tube can be so arranged as to insure complete liberty of movement for an instrument with a handle of varying length. The constructive problem, therefore, consisted in devising an arrangement of the electroscope, or its lamp, which should render possible an adjustment of its distance from the end of the tube, and should also allow of lateral movement. In order to attain the first purpose the lamp-holder is attached to a prism-guide set in the handle, and this prism-guide may be raised by a touch, and will remain in any position (see Fig. 9). As the axes *ef* and *mn* (Fig. 5) run exactly parallel, the eyehole of the mirror on being raised moves exactly in the line of prolongation of the tubular axis. Illumination is but little diminished at the end of the tube, as the light is chiefly parallel-rayed. The greatest distance between the lamp and the mouth of the tube is about 12 centimetres, so that even should the forceps be wrongly adjusted even by 10 centimetres, it can still be freely moved (Fig. 9).

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* The newest form of the electroscope, with divided mirror, has this screw transferred to the upper surface of the mirror-holder (see Fig. 11). Figs. 9 and 10 are incorrect in this point.

† See the German edition of this book.

The construction of the second device of the electroscope, permitting of the ready introduction of instruments, presented greater difficulties. As this object is particularly important in practice, I have endeavoured to attain it in three different ways, according as it might be necessary to introduce a rigid, thick or thin instrument.

In the first case—*i.e.*, when inner tubes, bougies, pump-tubes, and the like, are to be introduced—the tube-holder *r* (Fig. 5), with its envelope *l*, is fitted on the handle *k*, and can be turned round, so that the handle *k* may be turned round, and with it the lamp in the envelope. The spring *s* serves to limit the revolution of the lamp, and to make it snap automatically into the centred normal position.

It would be possible, of course, to introduce rigid instruments by raising the mirror-holder; but this is a complicated matter, and requires so much time that it would interfere with another duty—viz., the protection of the mirror from expectoration. With a little practice this can be effected by a lateral turn,

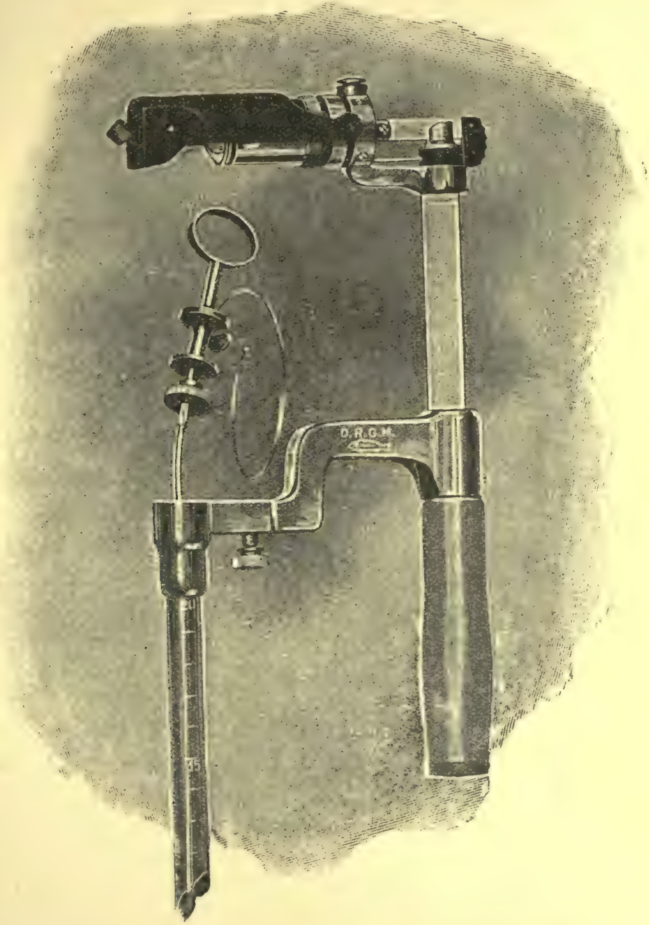

FIG. 9.—BRONCHO-ELECTROSCOPE WITH LAMP IN THE HIGH POSITION AND FORCEPS INTRODUCED.

just as well as when a frontal lamp is used, as it is only necessary to exert a small lateral pressure with the hand which holds the handle *k* in order to free momentarily the entrance to the tube.

A practised operator will do this quite involuntarily whenever a fit of coughing comes on. Consequently, the mirror-holder need never be lifted, except for the purpose of cleaning or of putting in a new burner, etc.

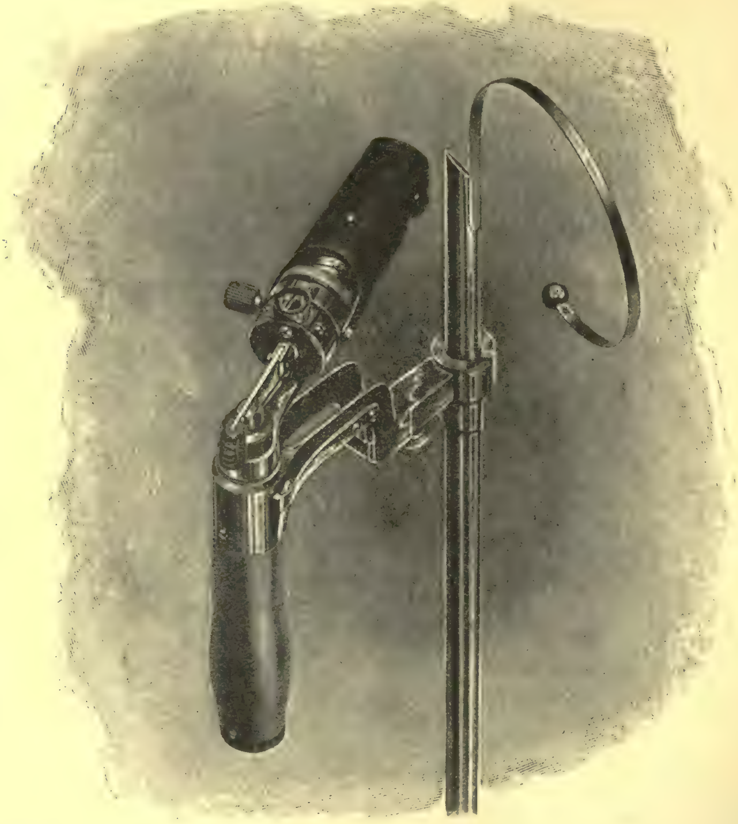

FIG. 10.—BRONCHO-ELECTROSCOPE WITH THE LAMP PUSHED SIDEWAYS FOR THE INTRODUCTION OF THE INNER TUBE.

Two other contrivances serve the purpose of introducing pump-tubes and thin operating instruments freely under the guidance of the eye; the lamp-holder is either drawn up (Fig. 9) so as to allow of the instrument being pushed past it, or the instrument is

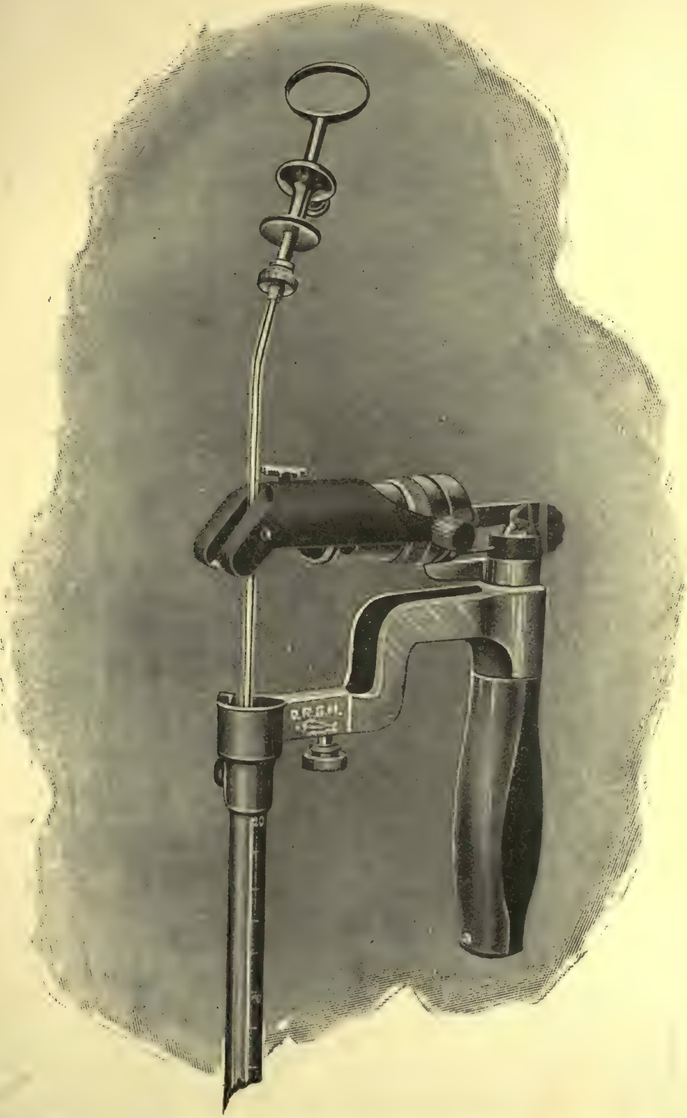

FIG. 11.—FORCEPS INTRODUCED THROUGH SLOT IN MIRROR.

passed through the slot in the reflecting mirror (Fig. 11). The former procedure is to be recommended in the case of all short operating instruments (*e.g.*, those for direct laryngeal operations) which leave room for a sufficient play between the tube and the lamp. The latter method is principally suitable when wool-carriers and long instruments are used. These may then be moved freely, vision is not in any way disturbed by the wide slot in the mirror, there is the further advantage that the lamp does not require to be drawn up, and the instruments may be of any length desired.

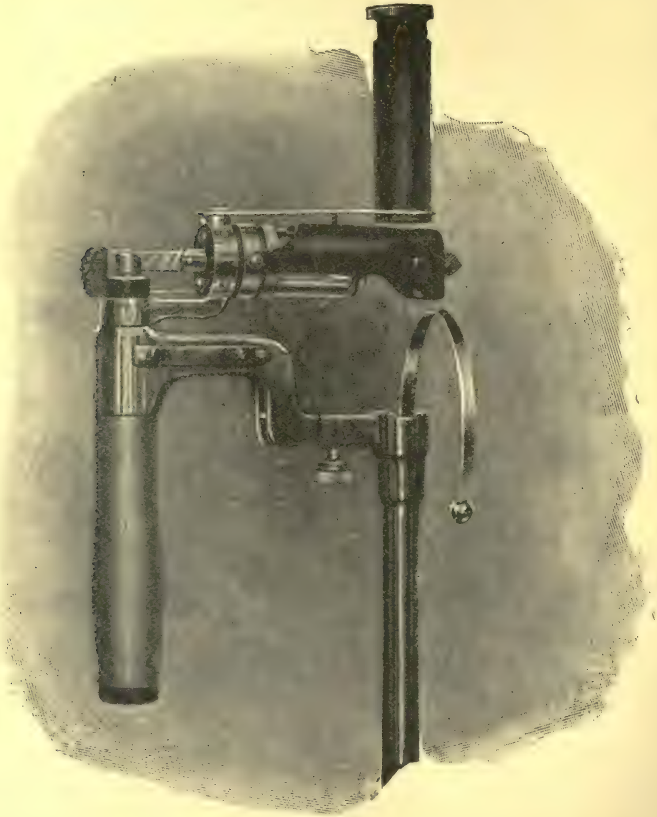

FIG. 12.—BRONCHO-ELECTROSCOPE WITH THE TELESCOPE IN POSITION.

In concluding this section, I must briefly allude to two auxiliary instruments of the electroscope—viz., the endoscopic telescope and the prism with double eyepiece.

The endoscopic telescope, constructed on Galileo's principle, can be readily attached to the electroscope. By merely turning the screw it can be focussed for objects between 20 and 50 centimetres' distance, and magnifies a surface four to nine times. In most endoscopic work, good illumination is of more importance than the size of the object, and therefore the telescope can be dispensed with. The illumination of images unfortunately diminishes so rapidly when the telescope is used that the latter has to be fixed above the mirror-holder, the slot in the mirror acting as a diaphragm. In the endoscopy of the air-passages the clouding of the eyepiece is very disturbing, and cannot always be entirely remedied by using Diaphanine. At the same time, I have occasionally used the instrument with much advantage for ascertaining and judging of slight alterations in the mucous membrane of the larynx, and for inspecting the deeper part of the œsophagus. The prism with double eyepiece, to be used simultaneously by two observers (Fig. 13), is also fixed on the mirror-holder in the same way as the telescope. It is only interesting in connection with endoscopic instruction, because by it the teacher can regulate the manipulations which are being carried out by the pupil.

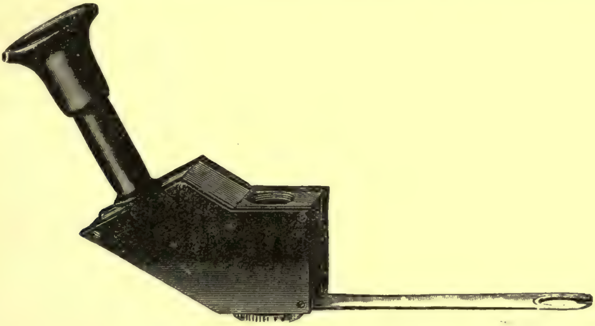

FIG. 13.—PRISM WITH EYEPIECE FOR SECOND OBSERVER.

The Endoscopic Tubes.

It is only necessary at this point to discuss briefly the extensible bronchoscopic tubes. What need be known about the various autoscopy spatulæ can be said when occasion arises.

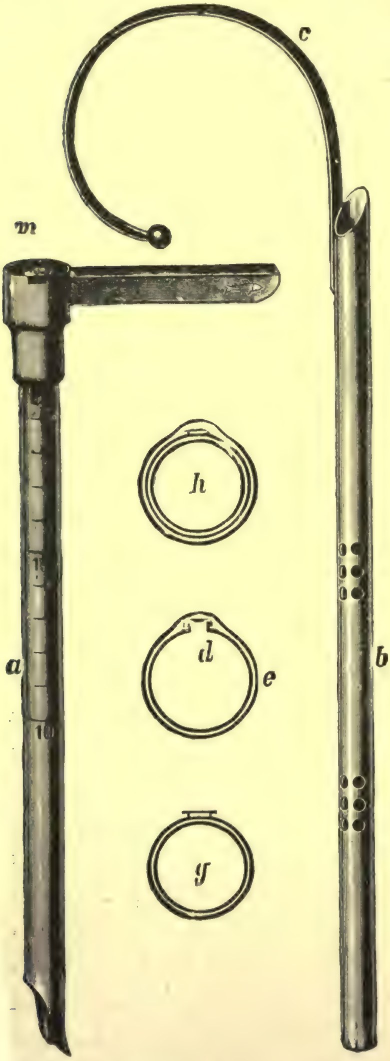

FIG. 14.—EXTENSIBLE DOUBLE TUBE. (After Brünings.)

My bronchoscope consists of two parts: the tube spatula *a* (Fig. 14), and the extension tube *b*. The relation between the length and diameter of the spatula has always to be such that it will reach the neighbourhood of the bifurcation. A centimetre scale begins at a distance of 10 centimetres from the free end. In the right-hand lateral wall is a longitudinal cleft, which is covered over by a soldered cap, so that (in cross-section *e*) the groove *d* is formed which ends a short distance above the sloping part of the spatula.

The extension tube *b* is straight below, and its upper end is cut off obliquely, and is provided with two sieve-like windows. These windows make breathing with the healthy side of the lung possible whenever the tube is introduced on the diseased side. Above this the spiral watch-spring *c* is riveted and soldered, as in section *g*; *h* shows the situation of the watch-spring when the extension tube is introduced into the tube spatula.

The peculiarity of the new bronchoscope consists in the arrangement of the watch-spring. Owing to this it is possible, while working, to have the most advantageous length of tube, because the end projecting from the tubular spatula rolls up spirally, and thus allows the eye to approach close to the instrument. The watch-spring is completely out of the field of vision, and also allows of the exertion of great force, as the guiding groove prevents slipping in every direction. In order to allow of control over the depth of insertion of the instrument, when the inner tube is being used, the watch-spring is provided with a centimetre scale, from which the total length of tube can be read at any moment.

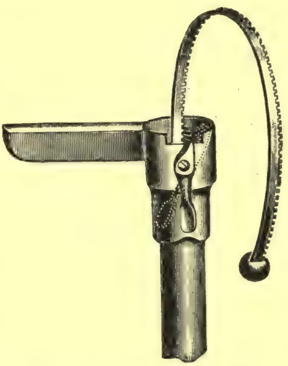

FIG. 15.—CATCH TO FIX WATCH-SPRING.

An improvement of the extensible bronchoscope, which serves to fix the mutual position of the two tubes as desired, must also be noticed. This consists of a small two-armed lever (Fig. 15), which, when its lower arm is pressed, catches with the upper toothed end in similar teeth of the watch-spring, and thereby retains it.

The practical significance of the extensible double tubes—the history and theory of which are fully explained in the German edition of this book—consists principally in their very easy introduction. This is chiefly brought about by the more effective orientation afforded by the large field of vision, and the very wide and short tube spatula, as well as by the sure and powerful manipulation of the short instrument and the dilating effect of the oblique end. Another advantage, as compared with older bronchoscopes, is the enlargement of the field of vision which has been increased two, three, and fourfold. It was possible by the introduction of double tubes to simplify the separate instruments, because formerly it was necessary to have each of the five widths of tube in three different lengths, and yet the surgeon was often uncertain which length might be most suited to the case in question.

I have selected the length of the new tubes in such a way as to admit of the most varied employment possible of the several component parts. I need only illustrate this in one case—say, in the case of No. 2—because what is said about No. 2 will apply to all the others.

With this the following procedures can be undertaken:

1. Upper bronchoscopy in men or women.
2. Œsophagoscopy in men or women.

With the tube spatula only:

3. Œsophagoscopy and direct hypopharyngoscopy, without a mandrin, in men or women.
4. Autoscopy.
5. Direct upper tracheoscopy.
6. Lower tracheo-bronchoscopy in men or women.

In order to make endoscopic work possible on individuals of all ages, from infancy upwards, the surgeon ought to have at least five different widths of tube. I consider it a great mistake to try to economize in this respect, because a patient may be seriously injured by having too wide a tube introduced; whereas, on the other hand, if the tube is too narrow, the result of endoscopy is doubtful. In the following table the dimensions of my tubes are given:

Number.	Diameter in Millimetres.		Spatula Length in Centimetres.	Total Length in Centimetres.	Application.
	Spatula Tube.	Inner Tube.			
2	12	11	20	40	Men, women.
3	10	9	18	37	Boys and girls from about the tenth year.
4	8·5	7·75	14	30	12 to 5 years.
4½	7·75	7	12	25	5 to 2 years.
5	7	6·25	11·5	23	3 to 0 years.
1	14	13	25	50	Œsophagoscopy.

On this table the following remarks have to be made. The numbers given in the first column are engraved on the square fixing pegs of the tubes (the older patterns are numbered in inverse order). Tube 4½ (formerly 1½) is not included in ordinary sets of instruments, and must be specially ordered. It is most desirable to possess Number 4½, as it covers those years (two to five, when foreign bodies have more particularly to be dealt with, and it is more suitable for such cases than the two neighbouring numbers. It is, of course, not meant that these divisions must be strictly adhered to, each number being to some extent applicable in younger or older cases. The matter will be fully dealt with in other chapters.

In conclusion I will give some directions for the

Management of the Tubes.

The extensible bronchoscopic tubes should be carefully tested with the electroscope before use. A frequent source of failure may readily be detected by fitting on the tube spatula and looking from its distal end up towards the mirror. The hole or slot in this should coincide almost exactly with the axis of the tube, even when the lamp is in the high position.

This test is very important for the smaller tubes, as with them an excentric position makes observation impossible. If the tubes have been bent by careless use, so that the light is no longer perfectly centred, this test will enable the fact to be detected and corrected. When the extension tube is used, great care should be taken that it slips easily into the tube spatula; the watch-spring should lie in the groove made for it, otherwise the tube will stick.

When the examination is conducted with the patient in the sitting position (*cf.* Fig. 30), the watch-spring will be on the surgeon's right side, and when the patient is lying down (*cf.* Fig. 70) it will be on his left. This arrangement has been made designedly, since the majority of operations are performed with the patient lying down, and so the right side of the tube is left free for the manipulation of the instruments with the right hand.

The introduction of the inner tube should be practised with the watch-spring in this position.

A still more important rule which should be observed is that the watch-spring should be grasped quite short when the inner tube is being pushed in, so that the hand is only about 1 to 2 centimetres above the end of the tube; consequently, the inner tube is only advanced by this distance at every push.

When the spring is held in this manner, it can stand the necessary force being applied to it; whereas if it is gripped long, the part which projects from the tube may be bent or broken off. In Killian's clinic hundreds of endoscopic observations have been made with the same instrument, many of them by beginners, and the watch-spring has not been damaged in the least. The weak spot is the junction of the watch-spring with the tube, and in cleaning it care should be taken that this joint is not knocked in a direction parallel with the tube, as it would be easily bent or broken off. If the advance of the inner tube, by means of the toothed spring, seems to meet with great resistance, it will usually be found that the position or attitude of the patient is at fault. This will be referred to again later on.

The employment of force is only permissible when the bearings are accurately known and the tube is under complete control.

This can readily be obtained by the use of the catch to fix the inner tube (Fig. 15, p. 39). By means of this arrangement the slipping up and down of the inner tube is prevented, and the tubes are used as a single firm tube.

If it is desired to overcome a resistance at a considerable depth, it is advisable to extend the double tube a fair amount, and to fix it before the introduction.

After a presentation of the field of operation has been effected, it is also advisable to lock the tubes by means of the catch, so as to guard against any possibility of the inner one slipping while the manipulations are being carried out.

The tubes are best sterilized by boiling, but any drops of water must be removed from the inside of the tube before use. When the tubes are put away, the inner one should be pushed into the other a little way, so that the steel spring lies completely free. This obviates the danger of the spring rusting owing to defective nickeling and imperfect drying.

When the tubes are being carried about, they are best pushed right into each other; otherwise they will not go into the case.

There is nothing special to be mentioned in connection with the autoscopy spatula.

The Endoscopic Forceps.

As the two previous chapters have treated of endoscopic illumination and endoscopic tubes, it might be expected that logically the description of the third section of instruments—*i.e.*, endoscopic operative instruments, should now follow. But this is a very wide term, including not only grasping, cutting, and probing instruments, but likewise all kinds of subsidiary apparatus for keeping the field of vision unobstructed. The discussion of these is advantageously relegated to those chapters which treat of their use.

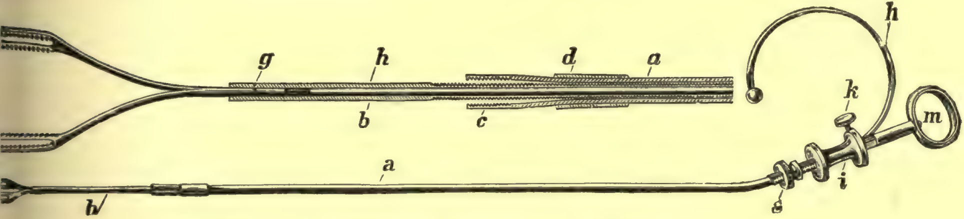

FIG. 16.—EXTENSIBLE FORCEPS. (After Brünings.)

The forceps, however, forms an exception, because it is typical of all endoscopic operative instruments. As, moreover, forceps instruments are rather complicated in structure, a special section is devoted to them at this point.

The endoscopic forceps should be not only neat and handy, but at the same time sufficiently solid in construction. Accordingly, joints and movable parts must at once be ruled out. The gripping portion must open by means of a special spring, and slip into a guide-tube on being withdrawn (Fig. 16, *a*). A distinction must therefore be made between the following separate constituent parts—the gripping portion with guide-rod, the guide-tube, and the locking mechanism.

The construction of the forceps joints are of special practical importance, as the success of endoscopic operations depends directly on their efficiency. For this reason I have devoted myself very specially to the examination of this point, and by studying the nature of foreign bodies and by making certain experiments, I have arrived at five characteristic forceps which may be regarded as typical and indispensable. The most important of them is the "Claw-forceps" (Fig. 17, A), which is essentially different to the bronchoscopic forceps hitherto employed, the latter being merely more or less ingenious modifications of surgical and anatomical forceps. In the bronchial tree, however, problems have to be faced which are entirely different from those occurring in other surgical operations. The surgeon is rarely in a position to get both branches of a forceps past a foreign body so as to be able to seize it firmly. Usually the forceps has to deal with a more or less obtuse-angled edge, or even a hemispheric surface, from which the ordinary coarse forceps simply glide off. I have therefore provided the claw-forceps with four fine needle-like teeth, which, on the slightest pressure, will insert themselves even into blunt-edged bodies.

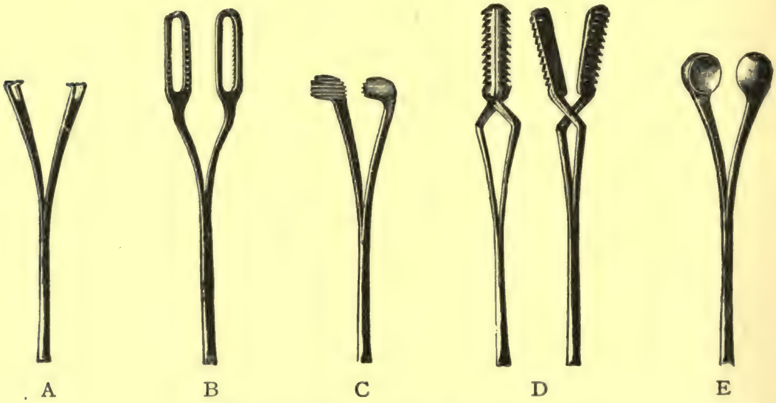

FIG. 17.—END-PIECES FOR FORCEPS.

This instrument with which I have extracted the greater number of foreign bodies, has proved itself of extraordinary efficiency. It goes without saying that in using it the most careful and gentle exploration is necessary, and anything like reckless use of force is to be avoided.

My second typical instrument for extracting foreign bodies is Killian's "Bean-forceps" (Fig. 17, B), a spoon-forceps, the branches of which are so hollowed out as to leave merely a thin frame. This forceps can only be employed when it is possible to slip it entirely past the foreign body, and is especially suitable in case of soft friable objects.

As a third typical gripping instrument I should like to mention von Eicken's "Needle-forceps" (Fig. 17, C). By bending the flat branches to a right angle it is possible to seize needle-shaped foreign bodies which lie parallel to the tube axis, and to draw them into the tube. In the case of hard, smooth objects, I would recommend that the branches be coated with the finest Kondom-gum or dipped into a solution of india-rubber (in benzole), which, on drying, leaves a very fine india-rubber coating. This instrument is also suitable for extracting small, and indeed very minute foreign bodies, because the plates close on their whole surface, and it is possible to follow exactly the action of closing.

In the fourth place I have constructed a "Hollow-body-forceps" (Fig. 17, D), which spreads outward on being drawn close. This serves for grasping hollow objects or such as have a hole (canulas, glass beads, and the like) through them, when it is not possible to pass the forceps outside the object.

I have also included in my ordinary instrumentarium the sharp double spoon (Fig. 17, E), which is meant not only for the removal of tissue for diagnostic purposes, but is also specially useful in the case of many foreign bodies.

With these five types of forceps all ordinary foreign bodies can be extracted with certainty. I may, however, remark at this point that exceptional cases occur in which it is only possible to reach a successful issue with special instruments. Most of these special cases occur with foreign bodies. In the case of foreign bodies in the œsophagus, the claw and the bean forceps are provided in two degrees of strength which correspond to the size of the foreign bodies with which they have to deal, but these can be screwed on to the bronchoscopy forceps

It is clear from the previous description of the manner in which the forceps is constructed that these can be screwed on to the wire indiscriminately.

This is done in the following manner: the retaining screw *k* (Fig. 18) is loosened so that the wire *h* can then be pushed down until it projects beyond the end of the tube *g*, and can then be screwed on to the square thread *a*. The wire *h* and the cylinder *r* are then pushed back again until the end of the forceps is secured, and the retaining-screw is then made fast. The forceps is then ready for use.

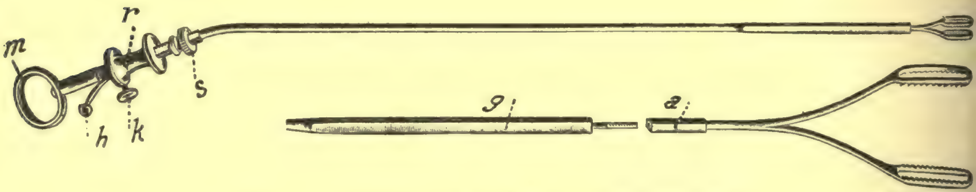

Fig. 18.—Endoscopic Forceps. (After Brünings.)

The advantage of this arrangement is that the parts of the forceps cannot work themselves loose from the square portion *a–g* by rotation round the longitudinal axis, and also that the whole instrument, in spite of its exceptional delicacy, possesses a considerable degree of strength.

The arrangement for closing is so simple that every forceps can be completely regulated with it. This arrangement consists of the thumb-ring *m*, the finger-roll *r*, and the regulating-screw *s*. The wire is connected with the finger-roll *r* by the vice-screw *k*, so that the forceps shuts when the roll is pulled.

As by this arrangement the forceps-tube is pressed by means of the thumb, the whole forceps retains its position unaltered, whether it is open or shut. For bronchoscopy two forceps about 25 to 35 centimetres long are enough. For specially difficult work on small children it is better to have a third pattern about 17 centimetres long. For œsophagoscopy an additional forceps about 50 centimetres long is required.

The non-extensible forceps which I have described can only be used with the electroscope with the slotted mirror (Fig. 11). This can readily be fitted to any of the older electroscopes, and I recommend it strongly. Otherwise it is necessary to use the extensible forceps which I mentioned at an earlier stage, and I must admit that they are considerably more troublesome and complicated, and that much greater care is required. As there are a large number of these older forceps, a description of them cannot well be omitted at this point.

The forceps-tube is, in this instrument, compensated by two small tubes, which push into one another (*a*, *b*, Fig. 19), the inner one of which has a screw thread *b* on the whole of its length. The outer one, which is of steel, with very thin walls, has grooves at its lower and rather thicker end *c*, and at this point is divided into several tongues. When the fine ring *d* is pushed against the end of the tube, the screw thread catches in the grooves, and fixes the position of the tube. When the ring is pushed back the thread comes out of the groove, the tubes are free from one another, and can be set to any length.

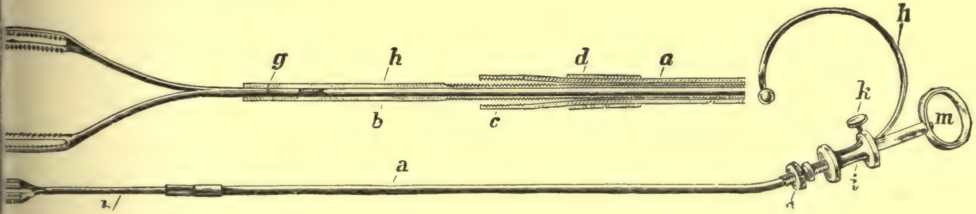

FIG. 19.—EXTENSIBLE ENDOSCOPIC FORCEPS. (After Brünings).

In order to be able to obtain a variable length of the wire *h*, I had its upper half rolled like a watch-spring, so that the end *h* unrolled itself spirally to a greater or lesser degree according to the position. It is fastened to the movable handle *i* by means of the screw *k*, and when in use rests between the index and middle fingers, where the movements of the hand do not interfere with it.

The method of using the forceps is as follows:

1. Shortening: The screw *k* is loosened, the clamping-ring *x* is pushed back, and the two tubes are gradually pushed into each other to the length desired, so that they can be held fast on both sides near the junction point. The clamping-ring *x* is then carefully pushed down again, and the forceps is made ready for use exactly as in the case of the non-extensible pattern.

2. Lengthening: After loosening the screw *k* and pulling back the clamping-ring *x*, the two forceps-tubes are drawn out from one another to the length desired, and the instrument is then made ready for use in the manner described in 1 above.

3. Taking to pieces: The end-piece of the forceps is unscrewed, and after the clamping-ring *x* is pushed back the inner tube is completely pulled out. The screw *k* is then loosened as much as is necessary, the nut *i* is pushed back on to the thumb-ring, and the wire *h* is completely pulled out upwards. The remaining parts of the forceps then come apart quite easily.

The cleansing and care of the forceps is of special importance, because fine steel instruments are difficult to protect from rust. This can be done with the greatest ease and certainty in the following way:

The forceps should be cleansed immediately after being used, without taking it to pieces, of all adherent secretions, etc., and if necessary it should be boiled. It should then be dried superficially, and plunged at once into a vessel containing soap spirit (chemist's soap spirit, diluted two or three times with pure alcohol), which quickly absorbs the water from the instrument.

After an hour the instrument can be taken out and allowed to dry in the air, and by this means the soap which still remains keeps the instrument sterilized, and by its slipperiness makes oil unnecessary.

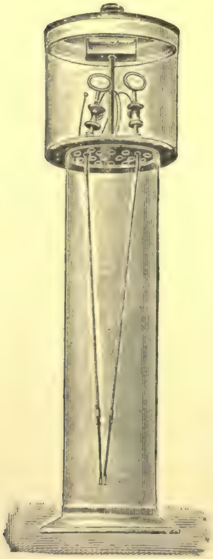

Fig. 20. — Standing-Glass for Forceps.

The most certain method is to keep the instrument continually in soap spirit, and for this purpose the instrument-maker provides a special standing-glass (Fig. 20).

III. ENDOSCOPIC PRELIMINARIES.

The reader will have obtained from the previous sections a close acquaintance with the appliances and their uses, and it is now his object to apply this knowledge to the living subject. It is almost invariable that practice should be begun on the dummy, although the value must vary exceedingly according to the particular nature of the problem. However well, for instance, the difficult perspective interpretation of cystoscopic images may be practised on models, yet on the other hand the main difficulties of the method can hardly be got over by means of the bronchoscopic dummy. I refer to the introduction of the tube, and the attainment of a comparatively quiet field of vision in a living subject whose reflex sensibility is readily excited and who is very liable to move. The processes that can be very well practised on artificial models are the endoscopic illumination, the interpretation of images seen through the tube with one eye, and the employment of surgical instruments. The most perfect broncho-œsophagoscopic dummy is that invented by

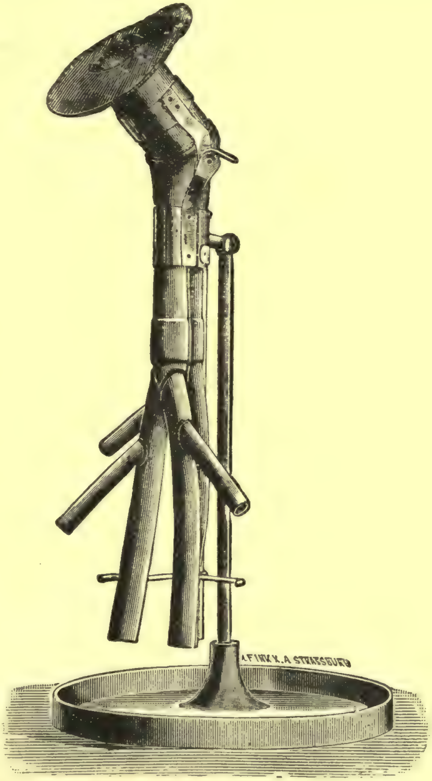

FIG. 21.—BRONCHOSCOPIC DUMMY. (After Killian.)

Killian (Fig. 21). I would advise those who cannot obtain this dummy to practise on the very suitable "foreign body tubes," introduced by Wild and von Eicken, which can be easily improvised. For these, india-rubber tubes of varying length and width, such as those used for conducting water, are necessary. The lower end is closed by a cork plug, above which "foreign bodies" may be placed. These tubes were originally intended for practice in illumination with the frontal lamp, as this was previously the most difficult point in learning bronchoscopy and occupied the main part of preliminary instruction. These special exercises in illumination are superfluous if the electroscope is used. Nevertheless, I find it advantageous to use the tubes in the following studies:

1. Estimation of distance, or the perception of difference of depth. The difficulty of this without binocular vision may be seen from the following simple experiment: If the operator shuts one eye and tries to touch some object sideways with his finger or a pencil, he only succeeds accidentally. Even when approaching it in a direct line from the eye, he feels quite uncertain as to the moment of contact.

The usual expedients for estimation of distance with one eye, inference from the size of the object and the degree of accommodation necessary, are more or less delusive in endoscopy, so that in the main it is necessary to be content with the successive observation of objects lying between the eye and the object, by means of which the eye gropes its way.

With endoscopic tubes the conditions are very unfavourable even for this kind of distance-judging, because the smooth walls offer no point of comparison, and the object observed—for instance, the bifurcation—moves freely in front of the end of the tube, until in attempting to pass it the surgeon suddenly stumbles on it. The beginner always has the impression that he is getting no nearer to the goal in view, especially while pushing forward the inner tube, because, as a matter of fact, there is no advance of the eye, and the other available criterion—*i.e.*, the sensible movement of the entire tube—is absent.

It is instructive to use these india-rubber tubes, and to be convinced of these inevitable delusions. It will then also be seen that it is impossible to utilize parallactic displacement as a substitute for stereoscopy which is lacking, because the small hole in the mirror does not admit of any lateral motion of the eye worth mentioning. Thus the last expedient must be resorted to—viz., that of moving the object laterally, or, what amounts to the same thing, the tube.

In all syringoscopic operations, constant excursions of the tube-end in every direction form a very important adjunct. They render visible that portion of the walls of the organ situated between the object and the tube-end at ever varying angles to the eye, thereby affording continuous information respecting the distances.

2. Deformities in the walls of the organ. The india-rubber tube affords an excellent opportunity for practice in the recognition of these very important and frequent endoscopic phenomena. The distinguishing of deviation and lateral compression stenosis and the various combinations of the two presents some difficulty at the beginning, even when examining with the tube, and consequently it is instructive to produce artificially the various images with india-rubber tubes. More detailed explanations would lead too far, especially as the dummy does not show the tracheal ring markings, which constitute so important a criterion for judging deformities.

3. The recognition of foreign bodies may very well be practised with india-rubber tubes, not only because the presence and nature of a foreign body is detected, but likewise its exact position, size, negotiability, and practical mode of extraction.

The diagnosis of the presence of a foreign body is not usually difficult even in the living subject, provided it is in the main bronchi, and not covered or rendered unrecognizable in consequence of lesion of the bronchial wall accompanied by profuse secretion. It is more difficult to determine with certainty the nature of a foreign body when discerned, because light-coloured foreign bodies may easily be mistaken for a light-coloured bifurcation spur or fibrous coating, while dark bodies may be confounded with coagulated blood. No doubt in the majority of cases the previous history excludes any doubt regarding the nature of the foreign body, although it may sometimes be unavailable or inconclusive. In particular, it does not throw much light with regard to the position and chances of extraction.

Exact knowledge of position is particularly important with foreign bodies of linear shape, the extreme case of which is a needle. The chances of extraction of such bodies entirely depends on the surgeon being able to seize the upper proximal end, or, if already embedded in the mucous membrane, to disengage it.

With oval foreign bodies which are more or less fixed, it is important for the surgeon to ascertain the exact position of the largest diameter, since the forceps should be applied perpendicularly to this plane. With foreign bodies of an irregular shape, it is often necessary to press the end of the bronchoscope firmly against the bronchial wall in several directions, so as to discover the place where a chink exists between the foreign body and the bronchial wall through which the forceps can be passed. This is generally present in the external lateral wall of the bronchus.

When foreign bodies which swell up, such as beans or peas, are being dealt with, it is often quite impossible to define the edge of the foreign body even when strong lateral pressure is exerted, as the bronchial wall is apt to curve round the foreign body.

I have found that the foreign bodies which present the greatest diagnostic difficulties when the dummy is used are a long hatpin with a black glass knob the point of which is directed upwards, and a pencil-cover the open end of which is uppermost.

It is obvious that the difficulty lies in the perspective foreshortening and in the erroneous impression of depth which is necessarily associated with the use of one eye only. The best method of overcoming these disadvantages lies in moving the end of the tube from side to side. Different diameters of the foreign body are thus presented to view, and so a more adequate conception is obtained. In other cases the difficulty of recognizing the foreign body lies in the fact that the quality of its surface cannot be sharply enough defined, and so confusion is apt to occur between beans and smooth pebbles, between glass beads and almonds, with the consequence that the wrong type of forceps is selected for extracting them. It should never be forgotten that the careful use of a probe is a great help in such cases. The use of the telescope attachment may also help in differentiating surface detail in foreign bodies or in the mucous membrane.

4. Extraction practice should be a regular part of the "course," as it gives the surgeon the necessary experience in the selection, fitting, and manipulation, of the forceps.

The selection of the proper end-piece for the forceps must be decided upon separately for every case, but certain broad rules may be laid down. The clawed end-piece should be used for foreign bodies which have a surface softer than steel, or whose roughness or projections are likely to afford a hold for the points. Round objects of glass or metal, teeth with a smooth surface, bodies which are friable or easily torn, and needles with their points upwards, are quite unsuitable. In the case of the last-mentioned it is especially important to work under accurate control of the eye, and to avoid the use of any instrument which has the least tendency to make the needle lie crosswise. The instruments which are indicated are the hook (after testing and loosening the upper end), the needle forceps, the loop extractor, and, in cases of necessity, the double curette. For bodies which are friable or easily torn, the best chance of extraction lies in the use of the bean forceps, but it must be borne in mind that these only work satisfactorily if they can be guided past the foreign body. An attempt of this kind, which does not, indeed, often occur in practice, must be made with the utmost care and without using any pressure.

The hook is a very useful instrument for getting past foreign bodies which completely fill the lumen. In doubtful cases, before using the bean forceps, the hook should be pushed past the foreign body and left in position. There is not then so much danger of pushing the foreign body farther down.

After the proper end-piece has been selected, the forceps must be adjusted to the right length. To ascertain this it is best to take the length of tube which first reaches the foreign body, and to add 5 centimetres to this, so that the hand can work freely when the electroscope is pushed up.

The proper method of applying the forceps to the foreign body is very important. It can be practised very well on the dummy.

The following points should be observed: Before the introduction, the blocking screw (see Fig. 19, p. 47) should be arranged so that the end-piece cannot open wider than is necessary to embrace the foreign body. It is then possible to direct the open arms of the forceps, and to seize the foreign body by pressing the fingers gently together. This pressure should be performed as gently and tentatively as possible, so that the hand may feel whether the forceps has caught hold.

The forceps and sharp hooks are delicately constructed, and are not meant to stand the application of much force, as this is rarely necessary in bronchial work. The rubber dummy affords no criterion on this point, as a smooth foreign body is much more difficult to extract from it than from a tube lined by a slippery, elastic mucous membrane. The beginner should rest content with a successful attempt at engaging the foreign body in the forceps, and should not risk damaging the instruments by trying to extract it, as the technique required for extraction in the living subject is quite different. It happens very seldom that foreign bodies are small enough to be extracted through the tube while this retains its position. As a rule the foreign body comes to a stop in its passage along the bronchial tree, because its size precludes any further progress. This necessarily implies that the lumen of the tube which can reach down to it is not likely to be large enough to permit of the foreign body being extracted through it. It is therefore usually advisable to try and engage an angle or projecting portion of the foreign body in the end of the tube, and to draw out the tube and foreign body together.

ENDOSCOPY ON ANIMALS AND ON THE CADAVER.

It has already been stated that the use of the dummy can only afford practice in lighting, observation, and in operating, and that it cannot give any help in the main difficulties of endoscopy, such as the skilful and certain introduction of the tube, and the maintenance of its position in spite of the numerous reactions of the living organism. To fill this gap many have suggested practising on animals, and it cannot be denied that, when rightly used, much can be learnt from this procedure.

But unfortunately there is also the danger that the surgeon who practises on an anæsthetized animal acquires a rough manner of operating which would be quite impossible on human beings. I am of the opinion that a completely correct manner is only to be learnt on human beings, as in their case the process is quite different than where other mammals are concerned, and that it can be learnt without further trouble by following the method which will be described later.

It is obvious that personal instruction is of the greatest importance—a systematic course on living persons, and even mere looking on at the work of a surgeon who is well versed in endoscopy. But those who have not this opportunity may, provided they make a careful choice of their patients (see later), practise diligently direct laryngoscopy, which is the starting-point for the examination of the air-passages, and put off bronchoscopy until they get the opportunity of a patient with a tracheotomy wound on whom they can, without undue pretension, make the first study of the bronchial tree with ease and certainty.

If anyone has to overcome a shyness (which is quite unnecessary) in examining the bronchial tree, he may look at it in animals, and convince himself that it is a solid and exceptionally yielding structure. For this experiment quite large rabbits are best (weighing at least 3 kilogrammes), as in their case the smallest tube can be inserted, which is not so with small dogs. The general anæsthesia required for the operation is best obtained in the case of rabbits by means of scopolamine morphine (morph. hydroch., 0·1; scopolamine, 0·01; salt solution, 10·0), given hypodermically two hours and one hour before the operation.

In the case of dogs, the object can best be gained by an injection of 1 to 2 grains of chloral hydrate, or by a pure solution of morphia; in the case of moderate-sized animals 0·1 grain is adequate (after injection regular vomiting occurs).

Endoscopy is best performed in the lying position, as it is then possible to put the larynx into a proper position and cocainize it completely by means of the spatula. This is much easier with dogs than with rabbits, though tracheoscopy is easier in the case of rabbits, as they do not cough.

Endoscopy on the human cadaver has this advantage over operations on animals—that the approximately normal shapes and sizes of the single endoscopic pictures can be impressed on the mind. It is also of direct value when practised on the bodies of small children, as affording familiarity with what is apt to be very difficult orientation. But in my opinion there is not much to be gained from the use of the cadaver so far as introduction is concerned.

When rigor is setting in it is very difficult, if not impossible, to make an introduction, and when rigor has passed off it is very easy. The beginner generally passes the tube into the œsophagus, which in dead bodies is quite open, owing to the absence of the tonic contraction of the œsophageal sphincter. The most important matter which can be studied on the cadaver is the endoscopic picture of the several branches of the bronchus.

I conclude this chapter with the advice that the greatest stress with regard to preliminary exercises should be laid upon obtaining a complete mastery over the instruments, and to this I have intentionally devoted considerable space. The technical aids which are available are, compared with cystoscopic instruments, somewhat complicated, and for this reason endoscopy is relatively more difficult.

CHAPTER II

LOCAL ANÆSTHESIA—GENERAL ANÆSTHESIA—OXYGEN INHALATION

THE insertion of this chapter should serve to free the description of the method of examination from theoretical discussions and repetition. Accordingly, the only matters which find place in it are the general principles of anæsthesia, and the consideration of the means which serve to produce it, while the special technique and indications will be dealt with separately in connection with each method of examination.

I have not been able to make up my mind completely to forego a description of the general principles of these three means which are so closely related to each other. Firstly, because this very important part of the procedure of endoscopy has hitherto been too much neglected; and, secondly, because in this matter the knowledge of the special technical directions for application no longer suffice for simple practical needs.

It will be seen later that in bronchoscopy a degree of local and general anæsthesia holds good in some circumstances in which the ordinary rules for dosage and application fail, and in which only general considerations guarantee certain working.

I. LOCAL ANÆSTHESIA.

1. General.

Local anæsthesia in the direct method of examination is exclusively an anæsthesia of the mucous membrane. Its object is to remove unpleasant tactile sensations, but above all things to abolish reflexes such as spasms, coughing, and choking. When the pain felt in the bronchi and the œsophagus is normally small, no means of deadening it is desirable, and where endoscopy is carried out with blunt-ended tubes is unnecessary. By this I mean, of course, the superficial pain felt through the specific nerve endings. The severe pain which comes from pressure and stretching can, however, not be banished by anæsthesia of the mucous membrane.

Local anæsthesia through injection, infiltration, and irrigation, has been by now well investigated and improved; but knowledge of anæsthesia of the mucous membrane (which may be called generally "diffusion anæsthesia") by the simple employment of useful means is correspondingly scanty and superficial.

The opinions, founded on rough empirical estimates, as to the most useful drugs and the best ways of applying them, are so contradictory that up to now no attempt at a critical exposition has been worth while. Unfortunately, certain experiments which I had arranged for, which included a clear statement of the question and an exact method of proof on a quantitative basis, cannot for other reasons be completed, so that the exposition can, for the present, only be very unequal and incomplete.

It is noticeable that reliable and consistent experiments are lacking with regard to the usefulness of the numerous preparations of cocaine substitutes, and trustworthy statements as to their relative value are completely absent.

The statements to the effect that experience shows that the use of certain drugs in a certain state of dilution will produce "anæsthesia" in the throat and nose are quite without confirmation.

The chief object is the dulling of the specific nerve endings which subserve reflexes. These are quite distinct from those which subserve painful sensations, since the reflex receptors, if, indeed, they are not identical with the end-plates, are at any rate more superficially situated than the pain receptors. Moreover, for a proper comparison of drugs, apart from similarity of molecular concentration, the relative efficiency—by which I mean the power of anæsthesia compared with their toxicity—must be considered.

The relative toxicity of those usually employed for mucous membranes has not been determined at all, or only to a small degree.

This depends on the rapidity of diffusion, on the size of the absorbing surface, and on the rate of the blood-flow, so that the toxicity shown when the drug is injected intravenously or subcutaneously is no criterion.

There is no such thing as a "maximum dose," in the proper sense, for local anæsthetics. For example, a rabbit is killed at once by an intravenous injection of 0·01 gramme of a concentrated solution of cocaine, whilst the injection of 0·1 gramme diluted with 100 c.c. of salt solution produces no such effect.

Accurate comparative estimates of their efficiency in paralyzing reflexes are complicated by the great difficulty that, apart from pathological cases (hysteria, multiple scleroses, bulbar paralysis, tabes, and syringomyelia), the reflex irritability of different people varies very considerably. In old people irritability is, as a rule, diminished, so that in such cases a tube can often be passed through the larynx without any anæsthesia whatever. The most irritable patients are middle-aged men, who often require two or three times the dose of cocaine required by women. This is due to the frequent catarrhs to which they are subject.

I must not attempt a comparison of the value of the many synthetic preparations, owing to my lack of personal experience of them, and will confine myself to giving my practical experience in the concentration and method of using cocaine. This limitation does not spring from a lack of appreciation of the synthetic preparations, for, on the contrary, I hold their scientific trial to be a very important consideration.

2. Method of Application.

The only point to be considered with regard to the normal way of applying local anæsthetics for the purpose of the direct method is the application of the drug to the mucous membrane. The molecules find their way to the nerve cells by diffusion through a more or less considerable layer of mucus or liquid, and after that through "tissue absorption." It is not known whether the so-called "absorption" is simply diffusion, or an elective solution, or an active cellular function. In any case, the process requires a very varying time, according to the kind and strength of drug employed, and this has to be taken into account in dealing with the special technique.

The rational method of application, aiming as it does at limiting the dose of cocaine, which in direct examination has always to be very large, is concerned with the following points:

1. To shorten the way to the cell as much as possible.
2. To apply the anæsthetic as long as possible to the part which is being treated.
3. To restrict absorption as far as possible to the place where it is required.

Instead of entering into theoretical discussions, I should like at once to mention some practical experiments which show how these objects can be best attained.

The object is to discover those factors which reduce the quantity of cocaine necessary when anæsthetics are applied to the larynx, without lessening the period of its activity or its efficiency. I found a suitable subject for making such comparative experiments in a patient suffering from bronchial stenosis. I treated his larynx with cocaine seventeen times, at intervals of three to five days, with a view to introducing bougies. He was rather more irritable than the average, and had moderate and fairly constant secretion.

The general conduct of the experiment, which at the same time affords an answer to a number of questions of dosing which will be discussed later, was as follows: In order to determine the actual quantity of cocaine absorbed (R), which is the only important point, it is necessary not only to know the quantity applied (A), but also the amount expectorated (E), and this is to be ascertained from the sputum. As there is no such thing as a simple quantitative reaction for cocaine I proceeded as follows: The cocaine to be employed was mixed to form a definite strength of solution with a blue colouring matter (indigo carmine), which, while very soluble in water, does not colour living tissues, and can easily be washed out of cotton-wool. For the purpose of obtaining a liquid by which to measure the relative amount of colouring, a watery solution of the same dye of exactly the same strength was used.

The quantity applied (A) could be seen directly from the spray apparatus and painting syringe employed (see below). The amount of expectoration (E) was ascertained colorimetrically in the following way: The patient was directed to spit out all the saliva into a porringer. This more or less blue liquid was then diluted with water to the extent of 250 c.c., and, after being thoroughly shaken, was filtered until it was clear enough for colorimetric measurement.* The strength of the control solution may be varied exactly by means of a burette, so that the amount of the applied colouring solution which was coughed up again can readily be seen. As the cocaine content may be regarded as proportionate to the intensity of colour, the experiment gives the value of E, from which it follows that R = A – E.

This series of experiments was intended in the first place to decide the question which of the two most usual modes of application — viz., painting or spray application — uses cocaine to the best advantage. A good-sized spray apparatus was used and directed as accurately as possible into the larynx. This was done under ocular guidance and suitable pauses were made. On the other hand, in the case of the painting syringe (see below) the consumption is recorded exactly, and the supply of cocaine on the swab remains constant.

The experiments yielded the following average values in anæsthesia of the larynx, with very slight variations :

	A.	E.	R.	
Spray apparatus -	2·0	0·72	1·28	c.c. of 20 per cent. cocaine.
Painting syringe -	0·5	0·14	0·36	solution.

In other words, the amount of cocaine absorbed during anæsthesia of the larynx is three times as great if a spray apparatus is employed instead of a painting syringe.

It is also worth noting that in the case of the spray only 2·8 parts of the applied cocaine is spat out again, while in the case of painting the amount is as much as 3·6 parts. This deserves special emphasis, because at each application of the spray I invited the patient to cough up immediately. If this is not done, the spraying method, which is absolutely non-irritating, will cause the absorption of cocaine to be still greater than was the case in these experiments. The cause of this is obvious. For one thing, a drug in the form of a spray can never be limited entirely to the part where it is required. Moreover, the solution, which only touches the surface lightly, takes a long time to diffuse through the mucous covering which conceals the tissues, thus leaving time for the solution to evaporate. There is also the uncertainty regarding the condition of anæsthesia at any given moment, as the upper part of the trachea is neglected in favour of the lower part, which has long since received a sufficient dose, etc.

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* The colorimeter glasses must be looked at against a dull white background, in order to compensate differences in the clearness of the solutions. The measurement will only attain the necessary degree of accuracy (about ± 8 per cent.) when there is no blood or coloured expectoration.

The superiority of painting over spraying and syringing may be expressed in three sentences—

1. A smaller quantity will suffice to produce a rapid effect because the brush touches directly the tissue otherwise covered by the mucus.
2. Localization can be strictly carried out, even in the case of parts which overhang or are not directly accessible to the spray, so that all unnecessary waste of cocaine is avoided.
3. Application with the brush allows of continuous control over the degree of efficiency obtained, so that reliable and progressive anæsthesia with a minimum of cocaine is rendered possible.

I have described these experiments in detail because anæsthesia by means of the spray and syringe is still prevalent, and has been applied in the direct method of examination, although the length of an operation (sometimes an hour or more), and the quite exceptional extent of the local anæsthesia, makes it necessary to apply such a toxic drug as cocaine as sparingly as possible. The view that painting is too trying to the patient is therefore not justified. In treating of the special method, it will be seen that in this way anæsthesia of the larynx can be obtained without exciting any cough at all, or so little cough that it is even necessary to ask the patient regularly to expectorate the excess of cocaine.

In Killian's clinic the use of the swab was considered as the only rational method even before I had justified it experimentally. Still, the ordinary method of using a piece of cotton-wool wound on a laryngeal probe or wool-carrier has certain disadvantages. It allows the greater part of the solution to escape on the first pressure and the wool becomes covered with a viscous layer of mucus, with the result that, at subsequent applications, only traces of cocaine are left, a circumstance which I have carefully examined with colour solutions. If a large number of fixed swabs are used, each one being employed once, the amount of liquid given off is more uniform, but as the amount left behind is beyond control all chance of estimating the real amount of cocaine consumed is lost.

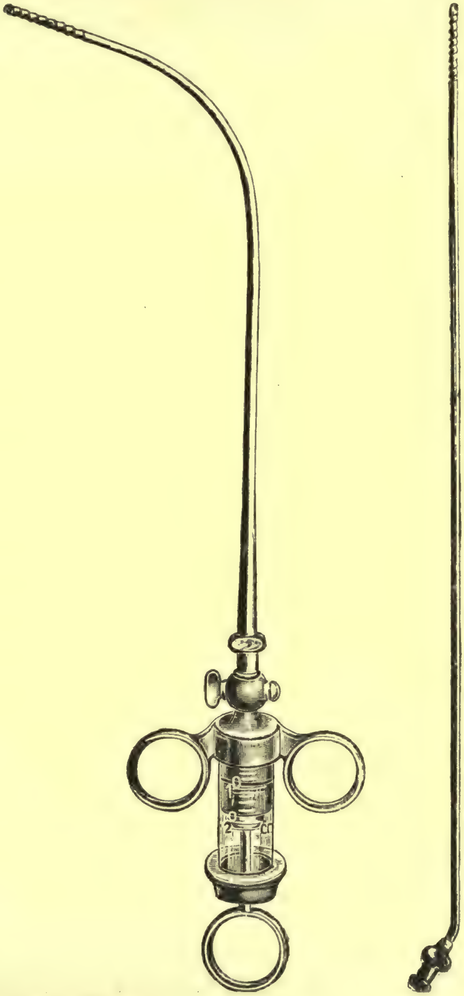

FIG. 22.—PAINTING SYRINGE FOR LARYNX AND BRONCHIAL TREE. (After Brünings.)

I have therefore had a small instrument made which I call a "painting syringe." While it gives off a very equal amount of cocaine, it allows the dose to be constantly controlled and saves the preparation of numerous swabs. The instrument (Fig. 22) consists of a graduated (record) syringe of 2 c.c. capacity, to which can be screwed two straight tubes 25 and 35 centimetres in length, one of which is bent like a laryngeal probe. The ends of the tube are pierced like a sieve and have a screw-thread for twisting on the cotton-wool. In filling the syringe it is best to take out the plunger, close the tap and pour in the cocaine solution from above till it reaches the zero line. About one-tenth of adrenalin solution may then be added, the plunger inserted and the contents mixed by turning round. In this position the tap is opened, and the plug pushed in until the twisted wool is soaked by the solution, or until the plunger reaches the zero mark. In the latter case the scale indicates immediately the amount of cocaine used at any moment.

I have intentionally omitted to provide the syringe with a stop-screw because I do not use the syringe plug while painting, but renew the cotton-wool as required in the intervals. Only when the bronchial end-pieces are used may it be advisable to syringe during introduction, because of the objection to working with the brush in the immediate neighbourhood of foreign bodies. More precise directions will be given in the section on special technique. Cocaine which has not been used may be allowed to remain in the syringe. The end-pieces must be cleaned and rinsed every time as they may be stopped up by the cocaine crystallizing.

Among its other advantages the painting syringe saves the operator the trouble of having a number of cocaine swabs at hand and of having to renew the supply in the course of the operation. Moreover, when working away from home, the cocaine can be conveniently carried in the syringe. The saving of cocaine is considerable, as there is no waste, and it is possible to regulate the dose very carefully.

3. Dose.

Like all narcotics, cocaine is a substance whose specific action on the cells does not depend on a stable chemical combination, but on a reversible procedure — namely, an elective solution. With such substances it is difficult to determine what would be a maximum dose, because the power of its action depends upon the concentration in the blood at the time. This is, on the other hand, dependent on the relation between intake and output, the rate of absorption and excretion, which can only remain constant for a brief period.

The maximum dose for cocaine is given, without any reason, as 0·05 gramme. This is the quantity contained in a cotton-wool brush containing 5 drops of a 20 per cent. solution, an amount which is exceeded tenfold in many operations. This, however, is justified, provided that certain forms of application, which will shortly be discussed, are adhered to. Whether or not there really is such a thing as idiosyncrasy forbidding the use of cocaine is a question which even the most experienced practitioners have left undecided. It has surprised me that, when surgeons have injected anæsthetics in large doses hypodermically, no striking hypersensibility has ever been observed, and Braun even denies its existence. Within my own experience, many alleged cases of death from cocaine, in which paralysis occurred immediately after administration, may perhaps be explained by reflex action. At all events, especially after anæsthesia of the turbinates, there is a number of more or less serious cases of cocaine-poisoning in which, considering the small amount of the poison employed, a kind of idiosyncrasy must be assumed; although here, again, it is necessary to consider very specially the particular part affected (proximity to vital centres), and its physiological significance (receptive end-organ for important reflexes).

Children show great sensitiveness to and little toleration of cocaine, as indeed of all narcotics. Very special care is therefore required, and the strength must be reduced in all cases to 10 per cent. With children, the comparatively harmless anæsthesia from chloroform should be employed in all cases where it may save the use of cocaine. Among the alternative preparations novocaine in particular appears to be effective with many children; at least there are many statements to this effect.

If there is no maximum dose of cocaine properly speaking even in the case of intravenous injection, much less can there be any question of a maximum dose when it is applied to mucous membranes. It will be seen later that a variety of causes makes it impossible to draw up a table. Of course this uncertainty with regard to doses must not lead to carelessness, but, on the contrary, make it obligatory in all direct examinations to employ every expedient for avoiding a dangerous dose. Among these may be mentioned, in addition to the method of application discussed in the previous section, the diminution of the rate of absorption by means of adrenalin, prolongation of the effective period by means of colloids, combination with general anæsthetics, and some other means.

With regard to the reduction of the rate of absorption on mucous membranes by means of the addition of adrenalin, there is no record of experiments. In the case of animals, the hypodermic dose which is fatal rises considerably when adrenalin extract is added. In order to obtain at least an approximate notion of the action in the usual anæsthesia of the mucous membrane, I have made the following experiments, which will be completed by further quantitative experiments.

First Experiment.—With one and the same patient, during a series of laryngeal paintings with 20 per cent. cocaine solution, a varying quantity of adrenalin was added, producing concentrations of 0·0, 0·1, 0·5, per thousand. The amount of absorption (R) is represented in the following table :

Adrenalin content per thousand - - -	0·0	0·1	0·25
Amount of cocaine absorbed - - -	0·35	0·36	0·41

The difference in these figures is so slight that, although there is considerable room for error, there seems to be no result, to speak of, from the addition of adrenalin. On close consideration this is not surprising, as adrenalin can, of course, have no important effect on the way that insensibility of the cells is produced, though it can affect the duration by influencing the circulation of the blood which carries off the substance. I was able to ascertain this influence quite easily in a second series of experiments.

In the second experiment, the same patient was only able to endure the bougie passed through the larynx for 15 to 20 minutes when treated with cocaine simply, but could endure it for 25 to 35 minutes when 0·1 per thousand of adrenalin was added. The addition of 0·25 per thousand did not have the effect of increasing the patient's tolerance.

It is regrettable that in cases of anæsthesia of the mucous membrane adrenalin does not prolong "the plateau" of the narcotic curve so markedly as it does in hypodermic cases. The reason of this is that adrenalin affects the mucous membrane comparatively slightly. If the effect could be prolonged or repeated without a second application of cocaine, probably the local anæsthesia would also be correspondingly prolonged.

In addition to adrenalin, I have also tested colloid solution as an admixture for prolonging the local effect. It is known from the medulla anæsthesia of Erhardt, with the addition of gum, that the rate of absorption may be produced by the addition of very viscous mucilaginous colloids. A circumstance which favours this addition in the case of mucous membranes is the fact that very viscous solutions remain at the required spot for a longer time than watery liquids.

I have tried adding gum-arabic and tragacanth in quantities of 5 and 10 per cent. The effect on the duration of anæsthesia is very pronounced, but I refrain from giving figures here as I was obliged to discontinue the experiments, because the thick, sticky solutions render the glasses, tubes, and instruments, so dirty and greasy that their employment is impossible. Unfortunately, there does not appear to be any alternative, free from these disadvantages, which binds the cocaine to the spot for any considerable length of time, so that recourse must be had to adrenalin preparations.

I have not been able to experiment myself with reference to the effect of the preliminary administration of codein, morphia, and bromide in rendering smaller doses of cocaine effectual, but this might be done by anyone who has the opportunity of examining the same patient frequently. There is no doubt that these substances, especially morphia, produce a distinct effect, and in Killian's clinic codein was successfully administered in cases of particularly irritable respiratory tracts. It is advisable to use these substances whenever cocaine seems to disagree with the patient, or would necessitate a dangerous increase of the dose. I shall revert to this subject farther on.

When there is much secretion the prompt effect of cocaine becomes practically reduced to zero. In the experiments already described with regard to the quantities of cocaine expectorated, I have always at the same time ascertained the quantity of sputum with which the unabsorbed cocaine was expelled. The result was that when there is more secretion the values of A and E rise very rapidly, and that E also rises considerably above the average. In other words, increased secretion demands a supply of cocaine several times greater because the substance is greatly diluted in the secretion and most of it is expelled at the same time. The fact that the quantity absorbed also increases somewhat may be due to the secreted matter being carried unnecessarily far in expectoration.

The knowledge of these facts is of practical importance because they show that, owing to the great difference of secretion, there can be no such thing as a uniform rule for the doses of cocaine. I was treating a patient bronchoscopically who had frequently been given as much as fifteen brushes of 20 per cent. cocaine solution. This is fifty times the so-called "maximum dose." I found afterwards that when he had really absorbed even 0·35 c.c. of 20 per cent. cocaine solution—about the thirtieth part of the above quantity—he showed regular subjective and objective signs of cocaine-poisoning (talkativeness and excitement). It was only the large amount which he expectorated that had protected him from being dangerously poisoned.

The question arises whether, when there is very great secretion, atropin ought to be given prophylactically in order to facilitate the use of cocaine. This is recommended by Ingals and Guisez for other reasons (facilitation of the operation). I believe that in this matter Killian is right in condemning the combination of such different nerve poisons, as their reciprocal effects cannot be checked.

The regular treatment of a patient with cocaine with a view to using the bougie gave me the opportunity of examining another question—viz., the connection of the amount of cocaine absorbed with the time of day, or, rather, with the state of the stomach (*i.e.*, its contents). The result showed that when the stomach was full the amount of cocaine absorbed, and especially the amount expectorated, was considerably greater. The reason of this is that during digestion not only the secretion but also the irritability of the mucous membrane is increased. This makes the operation more difficult both for the patient and the surgeon, and it should only be undertaken when the stomach is empty or washed out unless there is a very urgent reason to the contrary.

It will be seen later on that increased irritability generally constitutes one of the chief obstacles in the way of operations. When the mucous membranes are inflamed and there is hyperæmia, the effect of cocaine may be entirely suppressed in consequence of the extraordinary increase in rapidity of absorption. Even adrenalin cannot be of much use in such a case, because it hardly affects the hyperæmia caused by inflammation.

The very various phenomena of acute cocaine-poisoning cannot be described here. It is important to keep a careful watch on the mental condition and the pulse, and to notice any paræsthetic sensations especially in the hands. Amyl nitrite is thought to be an antidote, though there is some doubt about it because there does not seem to be any decided indication for the further vasodilation that it produces in the cerebral circulation, since in most cases cerebral hyperæmia already exists. More importance, no doubt, attaches to the early and symptomatic treatment with stimulants, among which I believe adrenalin occupies the foremost place (compare note on p. 87). This seems effective in the frequent cases in which cocaine-poisoning occurs in conjunction with vascular paralysis.

II. GENERAL ANÆSTHESIA.

If, in explaining the general principles of local anæsthesia, it was necessary to dwell at length on the method of procedure and the question of dose, it is possible to proceed more quickly in speaking of general anæsthesia because in this there are generally recognized methods to go by. But the question of indication is still very variously treated and therefore requires close attention.

The reasons for the divergence of views on the matter are various. Sometimes the operator has no clear desires in the matter and at other times his general bias with regard to narcotics is distinctly evident. A surgeon who is constantly using general anæsthetics will be more liberal in their application than a laryngologist who, being a complete master of the art of local anæsthesia, can much more easily dispense with general anæsthesia. It happens that the direct methods of examination offer a much wider scope for variety of opinion as to the degree of pain and fear which the surgeon may inflict on the patient; for the direct examinations and operations can all be carried out entirely without local or general anæsthesia, just as well as amputations used to be in the Middle Ages. It is only with children that there is any prospect of success if forcible measures are employed. The argument that endoscopy of the air and food passages can only be definitely recognized as a clinical method of examination if it can be carried out generally without anæsthesia is no less mistaken than the excessive preference for general anæsthesia shown by many English and American specialists. The truth lies between these extremes.

1. Indication.

Each case must be judged precisely on its own merits. In order to form a correct judgment, a clear conception must be obtained as to what can or cannot be effected in direct examinations by general anæsthesia both as regards the subject and the operator. It is a mistake to endeavour to remove the more or less distinctly defined difficulties in the way of introducing the tube by using chloroform, as the object of employing this drug is not to fill gaps in the technique of examination or to overcome the main difficulties without risk. Indeed, in a certain sense, it may be said that anæsthetics should only be used by one who can dispense with them. For the beginner, the feelings of the patient are an important guide to let him know whether his proceedings are correct and free from danger. It is true that this view is only justified to the full extent when my bronchoscopic instruments are used, as the introduction of the well-illuminated tube spatula is made so easy that the indications for general anæsthetics which used to arise from difficulties in introducing the earlier tubes are now absent.

The difficulties in the way of introducing a rigid tube which show themselves by the reaction of the patient can be grouped under three heads. These are

1. Reflex movements of resistance.
2. Reaction to the pain of pressure and stretching.
3. Psychical reactions (fear, etc.).

The operator should in every case be quite sure as to which of these three difficulties he is contending with, and whether anæsthetics are suitable for its removal. It is hardly possible to lay down general rules, but I should at least like to enumerate some of the most important directions.

1. Reflex Movements of Resistance.

I have purposely placed reflex gestures first, in order to make it plain that they constitute no indication for anæsthetics. Inhalation anæsthesia has the effect, like all processes which cut off cerebral control, of heightening rather than depressing reflex irritability. At the stage when the reflexes are abolished, anæsthesia always becomes dangerous. This was the reason why von Miculicz gave up inhalation anæsthesia, and, previous to cocaine, replaced it by supermaximum morphia injections by means of which he obtained, in the end, a relative suppression of reflex action. Even nowadays, when it is possible almost always to interrupt the chain of reflexes sufficiently by the local application of cocaine, this expedient is still of value, especially when it is desired to alleviate pain and psychical reaction simultaneously. But it will always be possible to stop short of the maximum dose, and in cases of reflexes of the respiratory tract large doses of cocaine can with advantage be substituted for morphia.

The dazed condition induced by morphia-scopolamine, which renders excellent service in painful cystoscopy, is not at all suitable for the purposes in hand. It only produces analgesia—and this is the reason of its usefulness in midwifery—while it leaves untouched, or even increases reflexes. Moreover, it deprives the patient of the power of suppressing reflexes at critical moments by an exertion of the will.

Although local anæsthesia is the chief means of suppressing reflex irritability, the expedients used by laryngologists in former days must not entirely be neglected. Before cocaine was introduced many operators endeavoured to prepare the subject for endolaryngeal operations by causing him for days before to put his finger as far down his throat as possible. Similarly, direct examination will be made easier if no attempt is made to force it at the first sitting, but if the patient is accustomed to it systematically by gradually introducing the spatula, pressing down the root of his tongue and painting the larynx.

Another expedient takes advantage of the physiological law that reflexes can be arrested by a strong psychical interest. The power of suggestion no doubt varies very much in different individuals, but there is no doubt that the tendency to cough will be greatly lessened if the patient is confidently assured that he can overcome the tendency by deep and regular breathing. The reflex closing of the mouth may be overcome either by waiting patiently, or still better by regular swallowing movements which, like regular breathing, are antagonistic to choking.

In combating reflex irritability, the position of the patient is also of importance. A sitting position will facilitate operations, especially when the bronchi contain much secretion, whereas the lying position may produce a constant cough. In these cases the complete emptiness of the stomach is just as favourable as the greatest attainable emptying of the lungs. Some time before the operation the patient should be placed on the side of the healthy lung with his body raised, so that the secretion can be drained from the diseased bronchial tree and coughed up. The avoidance of reflexes which arise from the collected sputum when the tube is introduced, will be dealt with when special methods are discussed.

2. Reaction to the Pain of Pressure and Stretching requires quite different treatment to reflex disturbances. The anæsthesia of the mucous membrane is of little avail against the painful pressure which has to be exerted on the root of the tongue

when the subject is difficult to treat autoscopically; it also helps very little in stretching the œsophageal orifice in difficult cases of œsophagoscopy. This is the place where general anæsthesia cannot be prescribed indifferently, but each particular case must be decided on its own merits.

In endoscopy of the respiratory and food passages, compared with other methods of examination, it is ten times less dangerous to employ general anæsthesia than psychical or physical force. Indications in such cases must be judged in the same way as in medicine generally. If important discoveries are made by feel during anæsthesia, though this is unavoidably painful, with what right can it be refused in therapeutic endoscopy, seeing that the operator here particularly depends on a quiet field of operation, unless his work is to prove a failure and the patient is to run a risk?

In cases of particularly difficult autoscopy (see later on), it must be remembered that even slight anæsthesia will reduce considerably the resistance of the tongue, which is the main obstacle to introduction; but when anæsthesia is slight, new difficulties arise from increased reflexes (choking and vomiting). Bronchoscopy, and especially œsophagoscopy make such great demands on the willingness of the patient, that in all cases he should be convinced of the importance, necessity and safety of the examination, and, when possible, he should have a say in the matter of anæsthesia. This makes it possible, in the case of adults, to moderate

3. PHYSICAL REACTION,

such as fear and excitement, in no small degree. Still more effective is the assurance of a patient who has already been examined, or, the assurance that the tube is only going to be introduced by way of a trial, and that this will be at once stopped if the patient gives a sign, say, by lifting up his hand. If the promise is promptly fulfilled, even though the tube has scarcely been in the mouth, the patient gains so much confidence that, by a strong appeal to his fortitude, success may be attained at the very next attempt. Vastly more is obtained in this way than by attempting to make light of the disagreeable nature of the patient's experience.

Of course, all this applies only to patients who are, more or less, amenable to rational appeals. With children the case is quite different. In their case, too, it is hardly possible to give general rules for the various ages. While for the ages from eight to ten the consideration mentioned above will have more or less weight, at the ages of four to eight, on the other hand, it should be remembered that it is difficult to obtain a satisfactory result by forcible means and that the younger the subject the more risk there is with cocaine compared with general anæsthesia. I believe, therefore, that at these ages the best results are obtained in bronchoscopy and œsophagoscopy by means of general anæsthesia and a minimum use of cocaine. Autoscopy and lower bronchoscopy can, of course, be carried out with local anæsthesia or without it. In the case of infants, where there is no question of using psychical influence, reliance will always have to be placed on the latter procedure.

2. Contra-Indications.

The contra-indications are mainly those relating to anæsthesia in general, but particularly those which have to do with the heart and breathing.

Bronchoscopy, and, indeed, even direct laryngoscopy, puts so great a strain on the capacity of the breathing mechanism by stimulating reflexes and by direct mechanical interference that, if there is any weakness, it is dangerous to increase it by the use of narcotics. This is noticeable even in the case of foreign bodies which completely block one main bronchus, but especially when there is deep anæsthesia of the larynx and the trachea. Severe dyspnœa constitutes an absolute contra-indication if not for direct examination generally at least for the use of anæsthetics. With children the greatest caution is required even in the simplest cases. Tracheotomy and the inhalation of oxygen are always the best course.

The general contra-indications for anæsthesia may be passed over here, but it may be mentioned that in the relative sphere of indications of direct examination they not infrequently include a contra-indication for this latter also. Thus, for example, it will be necessary in the case of old people to refrain from examining endoscopically a cancer of the œsophagus whose presence is clinically pretty certain, in cases where œsophagoscopy without anæsthetics is particularly painful.

3. Statistics.

I have gone into the question of general anæsthesia thus fully because it is still a subject of controversy and leaves room for a variety of opinions. This is not to be wondered at, since it plays such an important part in the practice of endoscopy. Certainly, if Gottstein's statistics up to 1907, relating to the bronchoscopic treatment of foreign bodies, are read, the impression will be gained that in more than 50 per cent. of all cases general anæsthesia becomes necessary. For instance, anæsthesia was used in 26 out of 46 cases in upper bronchoscopy, and in 29 out of 47 cases of lower bronchoscopy. But the relation of these figures, comparing the upper and the lower methods, show that the statistics require special interpretation. Thus, Gottstein, in view of the abnormally high figure in lower bronchoscopy, justly assumed that general anæsthesia was almost always adopted with a view to tracheotomy. Further, it must be remembered that more than one-half of the patients were under twelve years of age. If these cases, as well as the non-utilizable cases of lower bronchoscopy, are deducted, a somewhat different result is obtained, for it then appears that general anæsthesia was employed only in 29 per cent. of the cases of upper bronchoscopy for foreign bodies in patients over twelve years of age.

No doubt even this number is still very high as compared with the statistics from Killian's clinic which are given below. In order to explain them, insufficient practice in the use of the instruments and still more the difficulty of handling them must be taken into consideration. I believe I shall not be far wrong in expecting that the use of the newer devices will result in a great reduction in the number of cases in which general anæsthesia is employed.

In order to give a true idea of the practical significance of anæsthetics when the indications are correct, I insert a small table which shows the frequency or rarity of their use in the direct examinations and operations performed during recent years in Killian's clinic.

In judging of these numbers it must be borne in mind that they have reference only to clinical cases. All instances of endoscopy on practised persons, and for the purpose of teaching and demonstration, are excluded. On the other hand, in most examinations the duration of the operation has been increased in consequence of demonstrations for doctors or students. The numbers for lower tracheo-bronchoscopy, being too small, have been omitted, or, if given, are not reliable.

Nature of Examination.	Case Percentage of General Anæsthesia.		
	Over 10 Years.	Under 10 Years.	General.
Direct laryngoscopy - - - - - -	0	57	18
Upper tracheoscopy - - - - - -	0	100	4·4
Upper tracheo-bronchoscopy - - - -	3	100	22
Lower tracheoscopy - - - - - -	0	0	0
Lower tracheo-bronchoscopy - - - -	?	?	(6)
Direct hypopharyngoscopy and œsophagoscopy	3	90	6·5

It will be seen from the first vertical percentage column that in the case of adults, including children over ten, general anæsthesia was resorted to very rarely, and only for upper tracheo-bronchoscopy and direct œsophagoscopy. These were mostly cases of timid children or patients with a lesion which would render examination painful. The middle column shows that in the case of little children—most of them under six—a general anæsthetic was almost always used, often, indeed, for direct laryngoscopy if a direct operation was intended. It may be taken for granted that the counter-pressure method will permit some restriction in the use of a general anæsthetic even in these cases.

From the last column it appears that, taking all the cases into account, the percentage of anæsthesia is highest for upper tracheobronchoscopy. This fact is explained, as compared with œsophagoscopy, by the frequency of bronchial foreign bodies in children. The surprising result that the total for direct laryngoscopy shows a considerable percentage of anæsthesia is due to the fact that direct inspection in little children is generally the only chance for laryngo-tracheoscopy (difficult decanulation) and larynx operations.

4. Technique of General Anæsthesia.

Of the various forms of general anæsthesia the only one which has to be considered at present, as bearing on direct examination, is inhalation with chloroform or ether. Ethyl chloride is not suitable even for brief laryngoscopy owing to the short duration of the anæsthesia produced, whilst the administration of chloroform *per rectum*, which was very convenient for the purpose in hand, had to be given up on account of the unavoidable injury to the bowel.

Pure injection anæsthesia with morphia or morphia-scopolamine, apart from the disadvantages already mentioned in the case of indications, had the drawback that the depth of the anæsthesia is not variable, a property which is very desirable particularly in direct examinations. Combined narcotic effects may perhaps be advantageous in such cases. For preliminary injection of morphia this is known to be the case, and the preliminary injection of morphia-scopolamine, at least in cases where it is desired to avoid all psychic disturbance, may be recommended. In addition to this, it should be remembered that much chloroform is saved by the slightly dazed condition which is induced by scopolamine and morphia. For adults the dose is generally 0·0012 of scopolamine + 0·012 of morphia, two hours and again one hour before the operation, and this can be reinforced with chloroform at pleasure when desired. This is worth special consideration in the case of operations which last a long time.

Of inhalation anæsthetics, ether should only be used when the condition of the heart renders it advisable as it brings about hyperæmia of the mucous membranes and correspondingly increases their secretion. There is also the danger of fire when working with artificial light.

It has already been mentioned that in all kinds of anæsthesia the special reflexes of the air and food passages must be suppressed by local anæsthesia. If possible, the local painting required should be performed only after general anæsthesia has begun. The particular technique to be observed in particular cases, as well as all other special questions, can only be discussed later on because they require some acquaintance with endoscopic technique.

It will not be out of place in this connection to say a few words on the apparatus suitable for the purpose. Before the introduction of the tube (and in œsophagoscopy after introduction as well), the usual expedients may, of course, also be employed. Afterwards anæsthesia may be continued by means of the tube in the same way as through tracheotomy-tubes—*i.e.*, by holding a piece of cotton-wool of suitable shape, soaked with chloroform, at the end of the tube. The usual shape of mask is not convenient as it takes up too much room and also because it is desirable that the cover of the mask should be easily changed. The latter course is desirable for the reason that, when the tube is introduced, all expectoration (which has always to be reckoned with in bronchoscopic operations) is thrown straight on the mask and either stops the evaporation of chloroform or at least interferes with it.

The simplest expedient, therefore, would seem to be a small loose pad of gauze, sprinkled with chloroform, held before the end of the tube with the forceps used for cleaning the mouth; and this may be renewed as required. The concentration of the inhaled chloroform vapour may be varied conveniently by altering its distance from the end of the tube. This simple device has the disadvantage in bronchoscopy, in that the gauze obstructs the field of vision, and the operation has to be interrupted; moreover, the vaporizing surface is apt to be too small for intermittent use. I have therefore had a small wire mask made like a short cylinder (Fig. 23), on which the strip of gauze is held in position by means of the handle. This is a suitable arrangement for applying anæsthetics through bronchoscopy and tracheotomy tubes.

The mask is attached to the end of the tube and sprinkled with chloroform. The advantages of this are—an unobstructed field of vision and a large evaporating surface (about 60 square centimetres), while the breathing is left free and some protection afforded against the mask becoming soiled by expectoration. This little tube mask appears to me to be more convenient than the fixed connection of the tube with a Trendelenburg anæsthetic funnel (Killian) which hinders coughing up and interrupts the proceedings.

The administration of anæsthetics through a tube (Junker, Krönig, etc.) also has some disadvantages, for the following reasons: The apparatus at every pressure of the spray gives off from 80 to 100 c.c. of air mixed with chloroform vapour. If, when this is injected into the tube, it coincides with an act of inspiration, it will reach the lungs directly in full concentration, while if it coincides with an act of expiration it fails in its effect. This procedure takes no account of what is now known about the concentration of chloroform and injury to the lungs from anæsthetics, and the great favour in which it is held for operations on the head and neck can scarcely be justified in this respect even though its mode of application is extremely convenient.

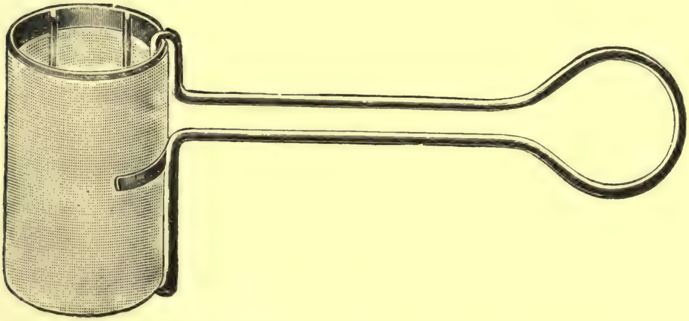

FIG. 23.—TUBULAR MASK FOR BRONCHOSCOPIC ANÆSTHESIA. (After Brünings.)

The chief error of pumping arrangements used hitherto (as opposed to the drop method or chloroform-oxygen anæsthesia) is as follows: The dose is not affected by corresponding variations of the amount of chloroform contained in the air respired, but by alternate administration of pure air and air saturated with chloroform—a procedure somewhat similar to alternately putting on and taking off a mask fully saturated with chloroform. I shall speak elsewhere of the rational construction of a pumping apparatus.

Nowadays there is no doubt that the most perfect anæsthesia by inhalation is obtained by respiring chloroform-oxygen. A very ingenious apparatus for this purpose is constructed, on Dr. Roth's directions, at the Dräger factory in Lubeck; but though it possesses great advantages, it has too complicated a construction and is so expensive that it can only be used in large hospitals. I have endeavoured, in view of the general importance of chloroform-oxygen anæsthesia and its special importance for laryngologists, to replace the large "Roth-Dräger" apparatus for administering oxygen anæsthesia, by a simple apparatus which should be both cheap and effective, and which might be recommended in the rare cases when specialists require to use general anæsthetics. A full description will be given elsewhere, but I will observe here that the administration of anæsthetics with the addition of oxygen is specially valuable to a laryngologist both because he has frequently to deal with dyspnœic patients, or his operations make special demands on the mechanism of breathing. I shall have more to say about this in the next section.

III. INHALATION OF OXYGEN.

1. General Remarks—Indications.

A short discussion on the inhalation of oxygen for therapeutic purposes is justifiable on three grounds: firstly, because endoscopic examinations of the air-passages have often to be undertaken while the breathing is obstructed, and these operations themselves add to the difficulty of breathing; secondly, on account of the general laryngological importance of inhaling oxygen; thirdly, owing to the importance of anæsthesia by means of chloroform-oxygen in general, and in particular when the power of respiration is diminished.

Before examining these points in detail, a few words are necessary on the general mode of operation and the indications for oxygen inhalation.

Leaving aside intermediate phases and combinations, two groups of causes which diminish oxidation can be distinguished. Either the quantity of hæmoglobin passing through the lung tissue in a given time is too small, or the quantity of oxygen in the alveolar air is insufficient. In the former case there are diseases of the blood or circulation ; in the latter case, diseases of the mechanism of breathing or obstacles in the air-passages.

The first group of diseases comes under internal treatment. The value of breathing oxygen is in this case but slight because the normal partial pressure of oxygen of the alveolar air suffices for the oxidation of the diminished amount of hæmoglobin. Even in the second case—*i.e.*, when there is a normal circulation of hæmoglobin—perfect oxidation may take place, notwithstanding the greatly diminished oxygen content of the alveolar air, because oxidation has the character of a chemical combination fairly independent of the degree of concentration. This is only true, however, in test-tube experiments. As regards saturation with oxygen in the living organism, time is a very important factor, and the admissible diminution of oxygen in the alveolar air soon reaches its limits; for on the way from the alveolus to the hæmoglobin the oxygen has to traverse a more or less thick layer of tissue, and this can only be accomplished by diffusion. The active power of diffusion is simply supplied by the degree of concentration, which practically depends only on the oxygen content of the alveolar air.

I make this brief general résumé here because the respiration of oxygen is often resorted to in any kind of dyspnœa without any special indications and the value of oxygen inhalation has been prejudiced by unavoidable failures.

The first group of diseases, including bronchial asthma and croupous pneumonia, in which the respiration of oxygen is frequently the only means of surmounting the crisis, may be passed over. There remain, as a really indisputable group of cases in which oxygen inhalation is indicated, all those diseases which involve narrowing of the air-passages.

That the oxygen cylinder may have a life-saving effect, rendering possible patient waiting or the carrying out of prolonged therapeutic manipulations, will be obvious from the consideration of the fact that, when oxygen is breathed, a far greater degree of stenosis may obtain than the maximum permissible when air is breathed, as air contains scarcely more than 20 per cent. of O_2. The fact that less carbonic acid is given off when there is insufficient exchange of gases is of smaller importance so long as it does not reach a narcotic concentration. A certain excess of carbonic acid in the blood may even be useful as this is a strong stimulus to breathing.

If I take from my own experience the most frequent cases in which oxygen-breathing has proved invaluable, the following groups may be mentioned:

1. Breathing of oxygen not infrequently renders tracheotomy unnecessary in the case of acute obstructions to breathing which may be overcome in a few hours—*e.g.*, laryngeal œdema and reactive swellings.

2. Breathing of oxygen admits of many examinations and operations being performed without tracheotomy—*e.g.*, speculum examination in serious dyspnœa, dilatation of larynx, stenoses, removal of tumours which are causing obstruction.

3. Hurried tracheotomy is unnecessary when oxygen is inhaled, and the operation may be performed deliberately and carried out in the best manner. Patients with severe dyspnœa are then able to endure the operation easily, lying on their back with the head extended. A light portable oxygen apparatus should be at hand, as a first expedient, when urgent tracheotomy is performed at private houses.

4. The endoscopic extraction of foreign bodies which cause obstruction is sometimes only possible with the assistance of oxygen-breathing. I remember a case of a moving foreign body (bean) in the trachea occurring in a child who became very

cyanosed and cold at the extremities. By the immediate application of oxygen respiration (at first artificially), I was able to bring the child back to a state of eupnœa, and as soon as the necessary apparatus was provided the foreign body was removed by upper tracheoscopy.

Inhalation of oxygen is, of course, of great importance in endoscopy for other purposes besides acute cases of foreign bodies. It need only be observed that direct examination has often to be effected with patients whose obstructed breathing has first to be accounted for. If it is also remembered that the introduction of a tube, from the mere fact of the unnatural position required, increases any existing dyspnœa, and that the excitement and reflex coughing greatly intensify the air hunger, it is not necessary to insist on the utility of the oxygen cylinder in endoscopic examination.

It is self-evident that in all the cases here mentioned, whenever general anæsthesia was necessary, the only kind of anæsthesia worth considering was that with chloroform-oxygen. It must, however, be repeated that in cases of serious dyspnœa any kind of anæsthesia is contra-indicated, and, generally speaking, endoscopy of the air-passages when there is shortness of breath presupposes a perfect mastery of endoscopic technique, tracheotomy and the application of oxygen. Threatened collapse may be warded off for a long time by the inhalation of oxygen. If, however, this expedient is pushed too far, collapse is correspondingly more dangerous. If breathing stops, oxygen is of no more avail.

2. Technique.

The technique of oxygen-inhalation requires a short explanation because the directions supplied with the apparatus are insufficient. In the case of active (spontaneous) inhalation of oxygen the matter is simple, and the apparatus and cost of its employment are very moderate. I think that the best apparatus is that made by the Dräger Works* (Fig. 24). In it the consumption of oxygen can be regulated, and it may easily be screwed on to the oxygen cylinders (chemically pure electrolytic product) which can be obtained from most chemists or at chemical laboratories. (The steel flasks containing 1,000 to 1,200 litres of compressed oxygen can generally be hired with a reduction valve.)

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* Obtainable from F. L. Fischer, Freiburg in Breisgau ; price about £3. The Dräger Works also manufacture a simpler apparatus at the price of about £1, but this does not permit of so economical a consumption of oxygen.

The gas passes the reduction valve V (Fig. 24), with the screw of which the steel flask is opened and closed, and enters the finimeter F, which is a manometer calibrated in atmospheres, indicating the pressure in the cylinder at the given moment. If this is multiplied by the capacity of the cylinder in litres (generally 10), the supply of oxygen is obtained at atmospheric pressure in litres (if the cylinder is full, 100 or 120 × 10 = 1,000 or 1,200 litres). From the finimeter the oxygen passes the gas clock M, the regulating valve of which (R) permits the rate of escape to be regulated between 0 and 10 litres per minute, which can always be read off.

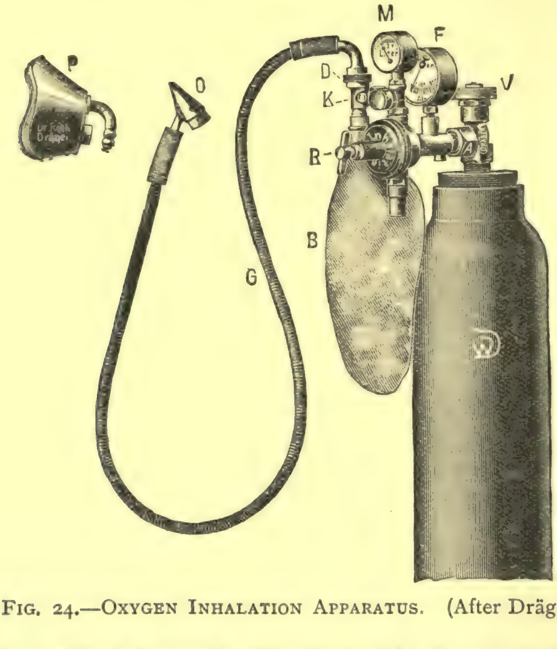

Fig. 24.—Oxygen Inhalation Apparatus. (After Dräger.)

For respiration of the escaping gas there is the mask P (for mouth and nose) or O (for the mouth only), the metal tube G, and the breathing-bag B. Above the gas-bag is attached an easily-working inspiration valve which only opens on inspiration and so prevents the return of the expired air into the breathing-bag. The expired air is carried off outwards by means of an expiration valve attached to the mask or mouthpiece.

The gas-bag with the valve mechanism constitutes a very important part of the whole apparatus as will be seen from the following considerations. If twenty breaths are taken in a minute—that is, three seconds to each breath—about one-fourth of the time is taken up with inspiration, whereas the much longer expirational phase together with the pause occupy three-quarters of the time; *i.e.*, a single inspiration lasts 0·75 second. Within this period the apparatus must yield the average respiratory quantity of gas of 500 c.c., so that with a continuous stream the consumption of oxygen will amount to 500 times 60 × 0·75 c.c. = 40 litres.

By interposing the gas-bag and valve mechanism the continuous supply of gas is converted into a rhythmical supply corresponding to the breathing. The bag fills itself during the expiration phase and breathing pause in such a way that, even at a slow rate of current, a sufficient quantity of gas for inspiration will have collected. There is therefore no waste of oxygen and the apparatus is required only to supply 10 metres per minute for twenty inspirations of 500 c.c. each.

The inhalation of pure oxygen is, however, but rarely required, and generally a dilution with an equal proportion of air is all that is needed so that from 4 to 6 litres per minute will do. The metal masks have a little lateral hole which provides the addition of air automatically. If pure oxygen is desired, this hole must be shut.

The price of electrolytic oxygen is at present from 5s. to 7s. per 1,000 litres, according to the cost of freight. The amount consumed in an hour will therefore cost 1s. 6d. But since the indications which have been given relate for the most part to its use for short periods, the price is trifling especially as the gas will keep for any length of time.

With regard to the use of the oxygen apparatus, the following points must be borne in mind. As appears from the description, the gas-bag can only fulfil its regulating functions if it is connected immediately with the air-passages so that no mixture with the outer air occurs. This is, of course, easily obtained when the mouthpiece is used, but in the majority of cases an active use of the mouthpiece on the part of the patient cannot be counted upon, and, consequently, one of the three sizes of metal masks for mouth and nose will be required. These three sizes should always be held in readiness. By selecting the suitable size and by careful adjustment, an air-tight connection can always be effected. This can at all times be easily ascertained from the collapse of the gas-bag and the audible sound of the valve corresponding to breathing. The outflow of gas should be regulated so that the gas-bag never gets entirely empty.

When oxygen is breathed through tracheotomy-tubes and introduced endoscopic tubes, it is, of course, not so easy to effect air-tight connection, and the operator has often to be content simply to allow the gas to stream out in front of the orifice of the tube. The rate of outflow will have to amount to 8 to 10 minute-litres in order to produce an equal effect. A special connecting part for bronchoscopic or tracheotomy tubes with the oxygen-tube can be had from Fischer (of Freiburg), but few opportunities of using it will arise, because it disturbs endoscopic work too much.

The technique of anæsthesia with chloroform-oxygen, which will be fully described elsewhere, is, generally speaking, the same as that of pure oxygen-breathing. The exact dose of chloroform, just as in the case of oxygen, becomes illusory if the gas mixture has to be employed without the connection being air-tight. In such cases the number of drops of chloroform has to be very much increased.

Finally, I should like to say a few words on the use of the oxygen apparatus in cases of collapse. Whenever artificial respiration is required, the mask must no longer be pressed on to the face because that prevents the tongue from being sufficiently protruded. A good supply of oxygen should therefore be allowed to meet the open mouth. If no spontaneous breathing sets in, passive inflation of the lungs must be resorted to as quickly as possible. If a tube has been introduced, it should be withdrawn from the bronchus and put into the trachea and left there. The surgeon can then with his own mouth blow into the tube rhythmically, inflating the lungs and compressing the thorax to empty them. Of course, the fact of having to use expired air is a drawback but it is well known that air may be used several times over. Unfortunately, it is not possible, or at all events it is dangerous to force oxygen in directly with the usual inhalation apparatus. In an urgent case the surgeon may breathe in pure oxygen himself and expire it into the lungs of the patient.

The attempt to inflate the lungs passively with the aid of the air-tight mask, which is pressed on, always fails because of the tongue slipping back. If, therefore, no introduced endoscopic tube can be used to effect the requisite air-tightness, there is nothing left except peroral intubation or tracheotomy, when the forcing in of air is not effected through the usual tracheotomy-tube but through some endoscopic tube or a catheter round which the trachea can be sufficiently tightened.*

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* I should not omit to mention the powerful analeptic effect of the intravenous adrenalin injection which has been described lately. Half to 1 c.c. of the usual 1 per 1,000 solution (still better the corresponding quantity in a solution diluted ten times) is injected into a vein. The mucous membranes are blanched almost immediately, there is an enormous increase of blood-pressure and the heart often begins to beat again under the stimulus of the adrenalin after all other stimulants have failed. (Compare John, "Klinische Erfahrungen über intravenöse Supraveneninjektionen bei schweren Herz- und Gefässkollapsen," *München. Med. Woch.*, 1909, 24).

CHAPTER III

DIRECT LARYNGOSCOPY

I. GENERAL.

THE method of direct laryngoscopy, or autoscopy as the author prefers to call it, advanced by Kirstein in 1894, aims at a direct peroral observation and treatment of the larynx in contradistinction to the classical indirect method with the laryngeal mirror.

Direct access is obtained by straightening the normal angular configuration of the passage by the use of straight specula. By this means the upper jaw and larynx are displaced backwards and the root of the tongue and the epiglottis pressed forward.

The value of Kirstein's method is great even in the present position of laryngological technique. This is mainly due to Killian's appreciation of its clinical possibilities and his elaboration of it, whilst its range of application and utility have lately been extended by the introduction of my method of counter-pressure.

Kirstein's method represents for all future time a cardinal principle in the extension of surgical knowledge which should never be underestimated, since there can be no doubt that an organ which is directly approachable presents far greater possibilities of treatment than one which is only seen indirectly with the aid of a mirror. It is, therefore, no longer possible properly to pursue the modern science of laryngology without a complete mastery of the direct method of investigation.

A detailed description of the indications for the employment of the direct method is so closely bound up with the clinical aspect as to lie outside the scope of this treatise. I will, therefore, confine myself, for the benefit of those who are not yet acquainted with the method, to a short review of the cases in which direct laryngoscopy presents the only likelihood of successful treatment, or in which it is obviously superior to indirect examination with the mirror.

The first group of cases for which the indirect procedure must be considered inadequate comprises the following:

1. Patients not amenable to the mirror: These include especially refractory and troublesome children, who must, if necessary, be examined by force, or after the administration of a general anæsthetic. I may instance the ætiological diagnosis of obscure cases of laryngeal stenosis, the accurate examination of cases of difficult "decanulation" (including the inspection and probing of the subglottic space), operations for papilloma, and the like. In the case of adults it should be remembered that direct examination occasionally succeeds when a gag has to be used to render examination with the mirror possible.

2. Foreign bodies which have become lodged in the larynx or are difficult to reach, especially when there is no certainty of the patient keeping quiet. The superiority of endoscopic extraction consists not only in the secure hold afforded, but also in the fact that rotations about the longitudinal axis can only be performed with straight forceps without which the process frequently does not succeed.

3. Cases in which, owing to pathological deformities, swellings or new formations, the mirror affords but an unsatisfactory view. To these belong, with gradual transitions, the majority of those laryngeal diseases in which the direct method affords a valuable supplement to the mirrored image. Under this head I will only mention cases of daily occurrence.

4. The precise topographical delimitation of malignant tumours, tuberculous processes, etc., which should in all cases precede any attempt at operation. It is well known that in diagnosis made with the mirror there is often much uncertainty, so that even an experienced practitioner is liable to surprises when dealing with the larynx opened up for operation.

5. Closely connected with the preceding cases is the accurate investigation of those sections of the larynx which are difficult of access, such as the posterior wall, the subglottic space, and the lower surface of the vocal cords, which is particularly important in the early diagnosis of tuberculosis and malignant tumours. The direct method of "laryngoscopia subglottica," as opposed to the mirror, affords complete surface inspection, such as is not otherwise obtainable or only from a considerable distance (the Killian position). Moreover, direct illumination is so brilliant, especially when the telescope which accompanies my electroscope is used, that it reveals the most delicate alterations of the epithelium which the mirror entirely fails to show.

6. Method of operation in parts difficult of access: This is the province of relative indication for the direct method in which each case must be judged on its own merits. It appears to me, however, that certain rules may be laid down. For instance, I have frequently carried out deep galvano-caustic puncture successfully by the direct method, even before the introduction of the method by counter-pressure. It is, moreover, far easier to make punctures of the posterior wall in the perpendicular direction by this method, with the least possible injury of the epithelium and a most accurate control of the depth of the puncture.

Polypi growing from the lower edge of the vocal cords and in the neighbourhood of the anterior commissure can be readily located, demonstrated, and easily removed with the aid of counter-pressure autoscopy.

It is evident that in such cases the measures to be taken will chiefly depend on the extent to which autoscopy is applicable in each individual. If autoscopy is at all satisfactory, the little operation which requires anæsthetic treatment of the larynx, even with the indirect method, can be performed with ease and confidence, and even an inexperienced hand can scarcely fail to complete it at the first sitting.

7. Extensive endolaryngeal operations under anæsthesia are practicable only by the direct method. I have constructed a special counter-pressure autoscope for operations under general

anæsthesia, which exposes the larynx in its whole extent, and also instruments for use with it.

8. Special mention must be made of the direct inspection of the the trachea and its location with the autoscopic spatula. It must also be remembered that tracheo-bronchoscopy and the scientific introduction of the tube necessarily presuppose familiarity with direct laryngoscopy, and that this is also desirable for the preliminary introduction of the tube for œsophagoscopy. The unskilled investigator of the larynx should also note that laryngoscopy with the prelaryngeal spatula affords him the opportunity of applying cocaine to the larynx under the direction of the eye.

9. Nor should the didactic value of direct views of the larynx be underestimated, as I have been able by the counter-pressure method to demonstrate cases to a congress of more than a hundred members. Laryngeal conditions gain in objective reality if they can be clearly exhibited to the doctors concerned.

The fact must be emphasized that the larynx, when viewed directly from a normal distance, gives a much more plastic, lifelike, and distinct impression than its reflected image, and that delicate details are distinguishable in a much higher degree. Thus, to take an instance, superficial fibrinous deposits and superficial defects, which in the mirror present a similar whitish colour, can be recognized at once even by the beginner as presenting plastic differences.

To avoid misunderstandings, I repeat that the foregoing brief scheme is only intended to give a résumé of the value of the direct laryngoscopic method and the extent to which it can be applied, and not an accurate indication. In order to obtain this it is necessary, as it were, to multiply the above data by a very varying individual quantity—viz., the extent to which the cases are amenable to autoscopic methods. This may be taken as a proportional number, if by it is understood the individual scope of autoscopy in relation to the individual extent to which the patient is affected; for, of course, any autoscopy can be carried out as a *tour de force*, so that in this way cases amenable to autoscopy would amount to 100 per cent. It will be seen later on that the percentage of cases in which direct examination may, and must, be expected even in relative indications is considerably lower, even when the very gentle method of counter-pressure is applied.

I should like to point out that in applying the direct method of examination to the larynx it is far more necessary to allow for individual peculiarities than would be the case elsewhere in the body. The passage to the larynx, as, indeed, the whole facial skeleton, is more liable to variation than is any other region of human anatomy. There are cases in which it can be straightened by means of moderate pressure with a tongue spatula, and, again, other exceptional cases in which pressure even thirty times as great will not suffice to overcome the resistance of the soft parts. This fact of itself leads to a kind of relative contra-indication which must be weighed against the relative indications for the method. In coming to a decision the chief stress must be laid on the special value of direct operation, even though this in some cases may demand the use of a general anæsthetic.

Absolute contra-indications for autoscopy are very rare. In the first place may be mentioned serious cases of dyspnœa, from whatever cause it arises. The administration of cocaine will then usually cause so much trouble that even an inexperienced operator will be duly warned against persisting in the examination. If, nevertheless, this is persisted in, it may easily happen that the powerful extension of the head, the pressure on the larynx, and the cramp-like reflex cough set up both by direct contact and the trickling down of saliva, taken together with some degree of mental anxiety, may cause attacks of suffocation. Consequently, if special indications render it necessary to risk the attempt, immediate tracheotomy should be performed, and the dyspnœa should, if possible, be overcome by the inhalation of oxygen before the examination is begun. If tracheotomy is decided upon, then the examination must, of course, take place after the operation.

As further contra-indications must be regarded all diseases which would render inadvisable any considerable increase of blood-pressure, especially advanced aneurism of the aorta, heart lesions where there is failure of compensation, a high degree of arteriosclerosis, or an apoplectic history. It scarcely needs to be stated that no serious examination should be attempted where the general powers are much impaired, or where hæmoptysis is threatened.

Besides these general preliminary remarks, I should like to urge the diligent practice of direct laryngoscopy, not only in view of its great practical utility, but because it forms the basis of all endoscopy of the respiratory passages. In bronchoscopy the greatest difficulty is presented in passing through the larynx, and this can only be accomplished by a thorough mastery of the technique of autoscopy.

With ordinary skill no danger is connected with direct laryngoscopy, and, if a judicious selection of cases be made, the discomfort which is caused to the patient will not be out of the ordinary. As a rule, patients who are easily or even moderately amenable to autoscopy say that it is the administration of cocaine which causes them the greatest unpleasantness. It is certainly advisable in early experiments to refrain from the use of counter-pressure, and this alone makes it necessary to begin with the mildest cases, the criteria for which are given in the following section.

II. NORMAL METHOD OF EXAMINATION.

The Kirstein method of examination may be considered as essentially a specialized tongue-spatula method, so that it is advisable to take it as the point of departure in this description. From it will be gained a knowledge of the most important criteria for judging of the possibility of autoscopy, and this knowledge will enable the student to select a suitable patient for his early experiments.

Criteria determining the Applicability of Autoscopy.

If a straight tongue spatula is employed in the horizontal position usual in pharyngoscopy, it is only rarely possible with strong pressure to render the upper edge of the epiglottis visible. But if the surgeon takes up his position in front of the patient, who should be sitting with his head moderately bent backwards, it is often possible, by pressing with the spatula in a forward direction, to obtain a view not only of the edge of the epiglottis but also of a greater or less portion of the lingual surface. It may even happen, in particularly favourable circumstances, that by introducing the spatula a long way and exercising a strong pressure a direct view of the arytenoid region may be obtained.

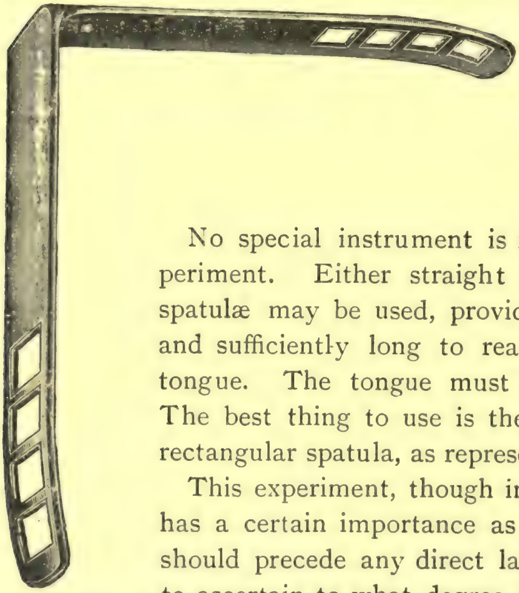


FIG. 25.—RECTANGULAR SPATULA. (After Brünings.)

No special instrument is required for this experiment. Either straight or angular tongue spatulæ may be used, provided they are narrow and sufficiently long to reach the root of the tongue. The tongue must not be protruded. The best thing to use is the narrow end of my rectangular spatula, as represented in Fig. 25.

This experiment, though in itself unimportant, has a certain importance as a preliminary, and should precede any direct laryngoscopy in order to ascertain to what degree it is practicable. It may be taken as a rule that autoscopy is the more easily performed in proportion to the degree of examination possible with the tongue spatula, but exceptions will no doubt occur. When the neck is short and the glottis is high, it is often very easy to reveal a large portion of the lingual surface of the epiglottis, especially when it is considerably inclined in a posterior direction. Therefore, when experimenting with the tongue spatula, it is necessary to notice the distance between the epiglottis or root of the tongue and the back of the throat. If the interval is small and cannot be much enlarged, even by considerable pressure, there will be difficulty in carrying out direct laryngoscopy even when the epiglottis is well in sight.

The test with the tongue spatula should not be slurred over, as for one thing it affords a means of judging the endurance and reflex irritability of the patient. After some practice, however, even external inspection will afford indications of the likelihood of autoscopy. A long and slender neck and movable Adam's apple are always more favourable for the examination than a short and stiff neck, strong neck muscles, and a short and thick tongue. This is the chief reason why women, children, and old people are, in general, much better suited for autoscopy than strong men.

One important criterion for the applicability of autoscopy, which will be repeatedly referred to later on and may be mentioned now, is the position of the upper incisors. When they are very prominent it is much more difficult to get the spatula in the direction of the trachea than when they are little developed or absent altogether. A gap of at least two teeth in the middle of the upper jaw considerably facilitates direct examinations.

When a patient is found who shows all or several of the criteria indicating easy autoscopy (positive test with tongue spatula; long, lean, and mobile neck; incisors wanting in upper jaw; good reaction to and tolerance of cocaine), the next thing is

Anæsthesia.

It is true that direct laryngoscopy is practicable even without cocaine, but this presents various drawbacks. In such a case it is necessary to place the spatula between the tongue and the epiglottis, and not on its laryngeal surface which is very irritable and likely to provoke reflex contraction. The pressure is, therefore, exerted on the valleculæ, and the epiglottis is indirectly erected as on the application of the Reichert hook.

The disadvantage of this prelaryngeal method, which was latterly exclusively recommended by Kirstein, is quite obvious. The field of vision is diminished in its lower part by at least the diameter of the epiglottis, even when this is fully erected, and in order to compensate this loss it is necessary very considerably to increase the pressure. The prelaryngeal autoscopy, therefore, without anæsthetics will be more trying to the patient than the endolaryngeal procedure.

As in the latter the end of the spatula is only advanced more or less upon the laryngeal surface of the epiglottis, it will usually suffice to treat this surface with cocaine. Careful experiments, however, have shown that the "autoscopic pressure" (see below) is much increased by choking sensations and reflex contractions of the tongue. Consequently, in the case of specially irritable persons, or when unusual pressure is required to displace the root of the tongue, it is advisable to treat it with cocaine. This, however, is not the rule; a steady and firm pressure on the tongue is much more easily borne than a gentle touch. It would, indeed, appear that strong pressure renders the excitable sensory nerve endings entirely insensible.

As regards the procedure in applying cocaine, of which the object and phenomena (a feeling of swelling) should always be explained to the patient beforehand, it is not necessary to say much after what has already been stated in Chapter II. I should like specially to recommend the following method as being both the safest and the least trying:

The painting syringe should be fitted with a swab of wool, rather large and not too loose, and should be filled with a mixture of 20 per cent. cocaine and adrenalin solution in the respective proportion of about 10 to 1. Under guidance of the laryngeal mirror the moistened swab should be placed on the upper portion of the laryngeal surface of the epiglottis for one or two seconds, without touching the neighbouring parts. Should the patient not cough spontaneously, he should be asked to do so; it is also very important that he should at once spit out any cocaine which may have got into his mouth.

All the surgeon has to do after this preliminary measure is to wait patiently for one or two minutes until the cocaine has taken effect. To renew the application too quickly only worries the patient unnecessarily without accelerating the effect. The second application, for which the painting swab must be moistened afresh with cocaine, will frequently excite no reflex action in the lower half of the epiglottic surface, provided a sufficient interval has been allowed, and it may accordingly be continued longer. After another pause, the application of cocaine may be continued until the surface of the epiglottis entirely ceases to respond, not only to the touch, but even to stroking movements. For treating the root of the tongue with cocaine, it is generally sufficient to pass the swab over it each time that it is taken out.

For more practised hands, I may state that examination is generally practicable even before reflex action has quite ceased, because the firm pressure of the spatula is much more easily borne than the light touch of the painting swab. In difficult cases, however, it may be observed that the requisite pressure in autoscopy may be considerably reduced by cocaine treatment even after irritability has ceased. In the case of protracted examinations (anything over ten minutes) an increased resistance to pressure may be noticeable, and this may make it necessary to renew the application of cocaine. All preparation should therefore be made beforehand, and autoscopy begun immediately after the application of cocaine has been completed, so as to take advantage of the best effects of the anæsthetic.

I have gone thus fully into this matter, although every student of the larynx is familiar with it, because there is a widespread prejudice against the application of the cocaine swab, although it is absolutely indispensable in the case of direct examinations. This prejudice is ungrounded except in so far that a hard pad of wool covered with mucus ought not to be passed persistently over the patient's larynx.

Surgeons who have not sufficient practice in treating the larynx will certainly experience great difficulty in applying cocaine preparatory to autoscopy. In case they should not wish to apply the spatula to the prelaryngeal region, they might apply a cocaine spray (not more than 5 per cent.), or at least let this precede the uncertain method of painting blindly. But considering the large consumption of cocaine, if the subsequent tracheal and bronchial examination should be necessary, it is urgently advisable to apply the painting swab as much as possible under the control of the eye. The following might do as a makeshift: The lingual surface of the epiglottis should be brought into view by the aid of the autoscopy spatula, using the light of the electroscope, as in the case of the preliminary tongue-spatula examination, and the swab should then be passed obliquely round the upper edge of the epiglottis. This procedure is more reliable and less trying than painting by feel, but even this requires some degree of skill in using the spatula.

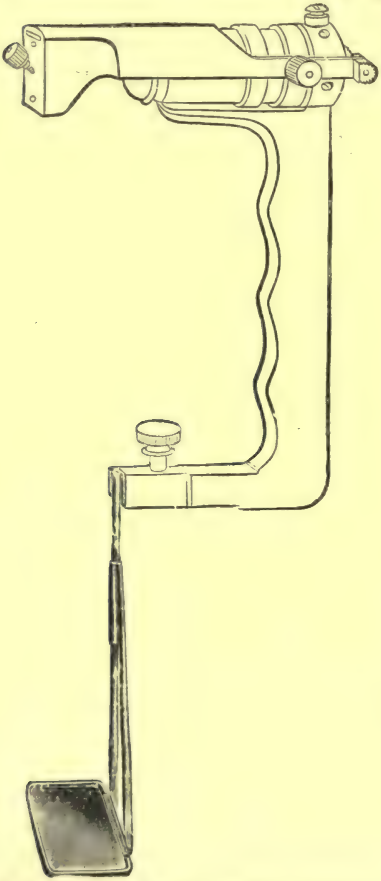


FIG. 26.—UNIVERSAL ELECTROSCOPE, WITH MOVABLE LARYNGEAL MIRROR, FOR SURGEONS. (After Brünings.)

For surgeons who work with my "Universal Electroscope" (see Fig. 26), I have had a movable epiglottis speculum fitted on to the handle (see picture), which renders unnecessary the use of a frontal reflector. It must, however, be observed that the main difficulty which insufficiently experienced surgeons have to contend with is the use of the laryngeal swab for cocainization.

The question of anæsthesia in little children and their examination is so different from the case of adults that it will have to be discussed in another section. I shall therefore now proceed to explain

The Examination

of an adult who is readily amenable to autoscopy, and has been sufficiently treated with cocaine. Special difficulties and artifices will be left for later consideration.

I must first add a few words on the selection of a suitable tube which in practice must, of course, precede the application of cocaine. It is true that direct laryngoscopy is, in any case, practicable even with the spatula tubes of my bronchoscopic double tubes, and it will be seen later that their application even presents advantages in certain cases. By the construction of special spatulæ for autoscopy I have obtained a wider field of vision and greater facility in operation.

These spatulæ (Fig. 27) are in the shape of a tube for one-third of their upper portion, in order that the field of vision may not be obscured by the teeth, lips, or beard. The middle third of the tube is open like a channel, but the edges of it are sufficiently raised so that when the tube is pressed against the tongue the latter does not obscure the field of vision. The lower third is much flattened, and has a sloping end.

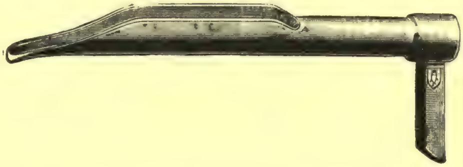


FIG. 27.—AUTOSCOPY SPATULA. (After Brünings.)

The spatula affords a field of vision twice as great as the closed tubes, and that, too, without causing the patient any greater inconvenience. It is 15 centimetres in length, and is supplied with my instrumentarium in two different widths—14 millimetres and 11 millimetres. Besides this, there is also a special spatula for children, rather differently constructed, which will be described in Chapter VI. (Examination of Children). The points on which the selection of a suitable spatula depends cannot be considered until later on, but I may now remark that there is no practical reason for using the ordinary terms "spatulæ for men" and "spatulæ for women" as opposed to "spatulæ for children." For a typical examination the spatula with a diameter of 11 millimetres may be used.

After the patient has removed his collar, any obstructing articles of clothing and false teeth, if he has them, he should be placed on a seat 20 to 30 centimetres in height, in such a manner that the operator has the light (window or lamp) at his back, thus shading the patient. The room must be darkened at least as much as for indirect laryngoscopy. If there is an assistant at hand, it is advisable for him to support the patient from behind, and to keep his head and the upper part of his body in the requisite position (see Fig. 30) The arms of a chair or a head-rest are only in the way.

After the spatula has been fitted to the electroscope, the light arranged, and a damp rag placed ready for cleaning the mirror of the electroscope, if it should be required, the spatula for autoscopy and the mirror of the electroscope should be slightly warmed over a lamp, and all is ready for the actual introduction of the tube. This process may be divided into three stages in the case of all direct examinations of the air-passages.

First movement: Bringing into view the lingual surface of the epiglottis.

Second movement: Passing beyond the epiglottis and pushing it aside.

Third movement: Pushing the tube deeper, possibly through the larynx.

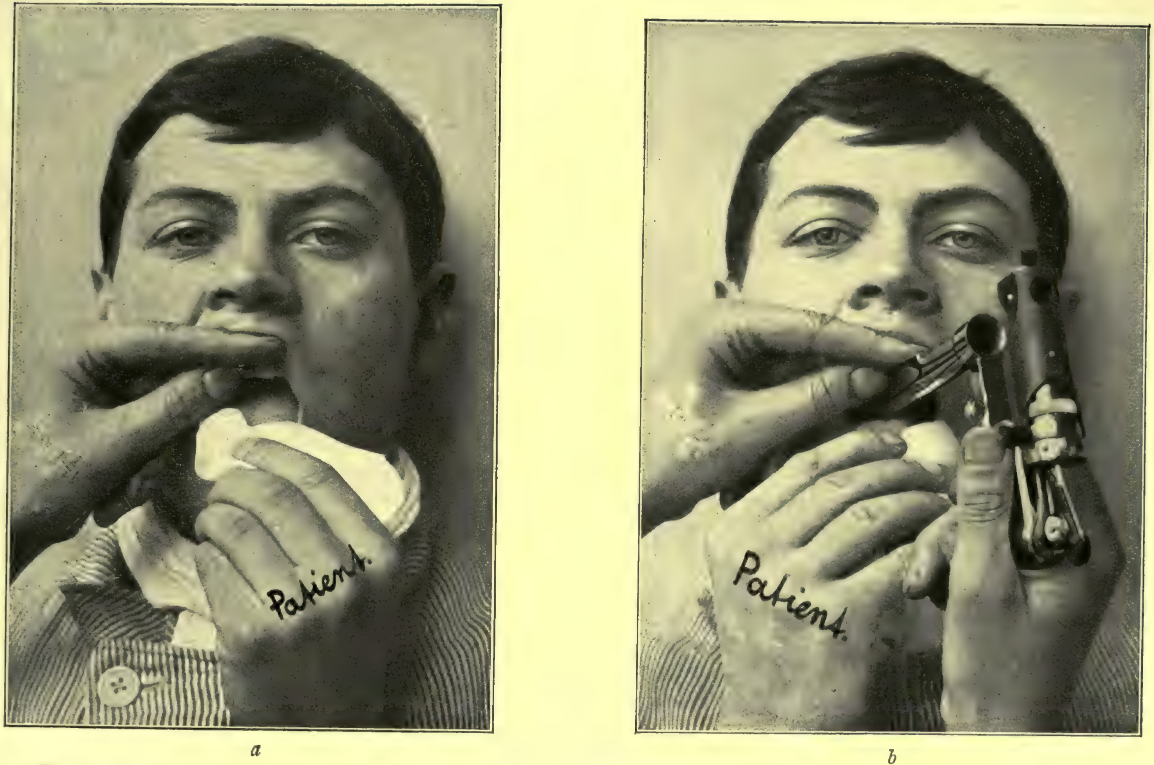
This formal division, which suggested itself to me spontaneously during practice, is no unmeaning pedantry. It keeps beginners from making typical errors, and even practised hands who have adopted personal variations will find it a useful guide in difficult cases.

FIRST MOVEMENT.

In bringing the lingual surface of the epiglottis into view, the operator is enabled to ascertain the correct medial position and the proper depth to which the spatula should reach. Such orientation is absolutely necessary, because the narrow closed tube only presents a very small field of vision which does not offer any indications, except the epiglottis, for judging of the correct position of the tube.

It is best to proceed as follows: The patient should bend his

PLATE I.



FIGS. 28 AND 29.—POSITION OF THE HANDS FOR THE INTRODUCTION OF THE TUBE (PROTECTION OF THE LIPS).

To face page 100.

head back very little, and should hold his tongue fast with his left hand to prevent it moving inconveniently (Fig. 28). The surgeon should then introduce the spatula exactly in the middle line, not too vertically, so that when the tongue is depressed the upper edge—*i.e.*, about 5 to 7 centimetres—of the epiglottis comes into view. The surgeon's eye should remain all the time close over the slit in the electroscopic mirror.

In order that the spatula, while being pressed down, may not slide off laterally or downwards from the raised tongue, and in order that the lips and teeth of the patient may be protected from pressure, I urgently advise the surgeon to proceed as follows in all direct examinations: The left forefinger should push up the upper lip until the thumb, which is pressed against the forefinger, finds a secure support against the upper row of teeth (Fig. 28). The tube should be introduced into the angle formed by the thumb and forefinger, in such a manner that the thumb prevents lateral displacement, while the forefinger protects the teeth from pressure and serves to guide the tube when it is introduced farther (see Fig. 29).

This manipulation, which even inexperienced operators very easily acquire, is much safer and less trying to the patient than the introduction of a finger into the mouth and the vain endeavour to find a support from the movable soft parts. Moreover, this method, owing to the position of the forefinger, alone enables the teeth to be protected from pressure or even from contact with the tube. It also entirely does away with the strong friction which, in any case, the teeth exert upon the tube, as it is possible to control the advance of the tube quietly and progressively with the forefinger.

To return to the introduction of the tube, after the free edge of the epiglottis, which is often only attained after having pressed down the tongue at various places, has been brought into view. The end of the spatula should be slightly raised, and passed under the control of the left hand, over the epiglottis for about 2 centimetres exactly in the mid-line, so that it has altogether been moved about 8 or 10 centimetres inwards.

SECOND MOVEMENT.

I now come to the actual autoscopic displacement. The patient should let go his tongue and lean his head back a good deal more (see Fig. 31). At the same time, while keeping exactly to the middle line, the surgeon should exert powerful pressure in a forward direction on the root of the tongue, but should not allow the tube, which is resting in the angle between the thumb and forefinger, to move in any deeper. What has to be aimed at is rather a purely rotary motion about a horizontal axis situated in the middle of the spatula, together with a gentle forward pull.

It is very advisable during this autoscopic displacement to make the patient utter a continuous sound. This not only diminishes the tendency to pressure, but also renders orientation much easier. For whereas the back of the throat, which is immediately in view, affords no useful landmark, the arytenoid cartilages which then enter the field of vision show at once, by their symmetrical vibrations, if the tube has swerved from the medial plane, and this deviation can consequently be corrected while further displacement is proceeded with.

The amount of pressure required in order to bring successively into the field of vision the arytenoid cartilages, posterior commissure, the vocal cords, and the anterior commissure, varies exceedingly in different individuals, as will be seen farther on. On the average it amounts to about one-half of the pressure which the hand of a strong man is, in fact, capable of exerting in that particular position (10 kilogrammes). As the root of the tongue is capable of supporting considerable pressure, there is not much danger to be apprehended even in the case of a beginner, provided that he avoids lateral deviations, and, above all, does not introduce the tube too deeply. If a short autoscopy spatula is used, it is practically impossible to enter the sinus pyriformis. Whenever there is any doubt, it is better to hark back and begin again with the first movement.

PLATE II.

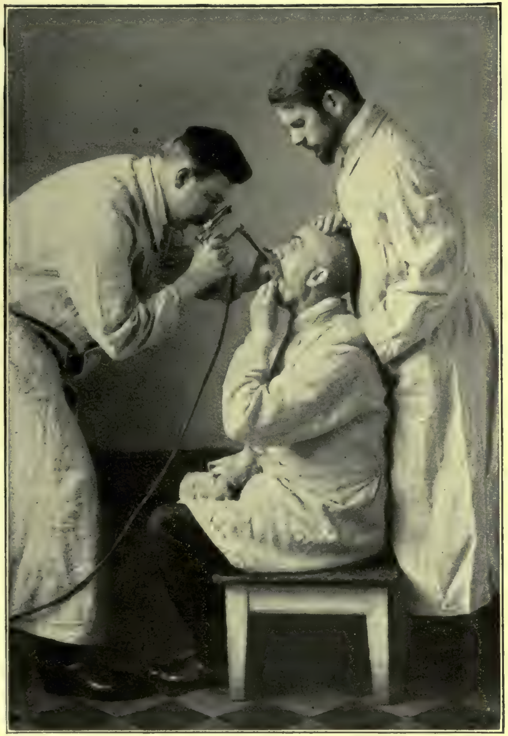


FIG. 30.—STAGES I. AND II.: RECOGNITION AND PASSAGE OF THE EPIGLOTTIS.

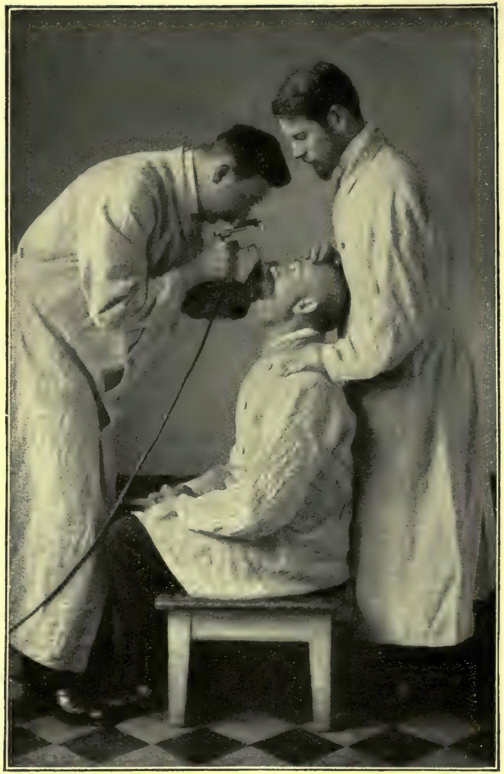
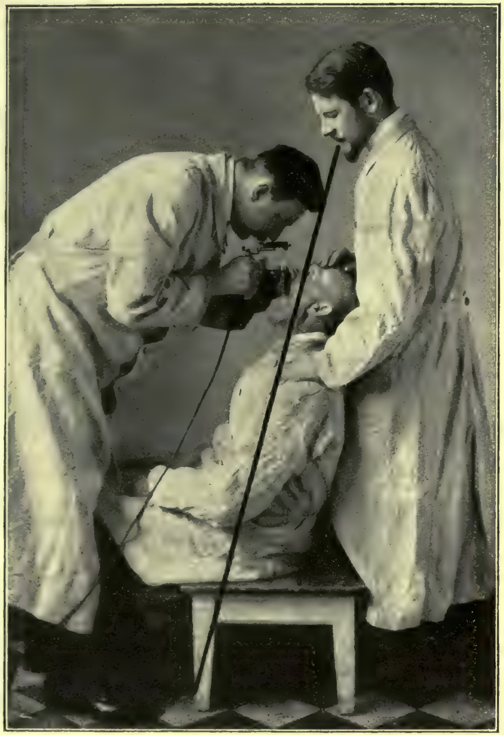


FIG. 31.—STAGE III.: FORWARD PULL (WITH THE TUBE HIGH).

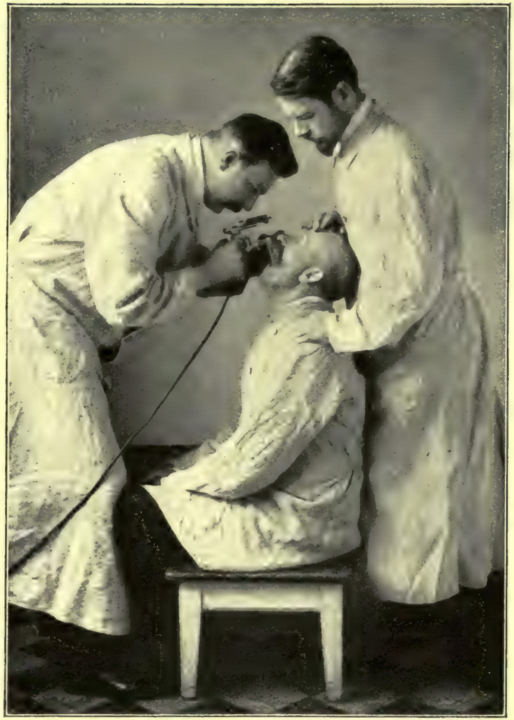
To face page 102.

PLATE III.



c

FIG. 32.—FAULTY POSITION (PATIENT SLIPPING FORWARD).



d

FIG. 33.—STAGE IV. : DEEP INTRODUCTION.

To face page 102.

THIRD MOVEMENT.

The deeper introduction of the tube and the passage of the glottis no longer belongs to laryngoscopy proper. Nevertheless, it may become necessary to increase the depth to which the tube is introduced in the second stage by 1 or 2 centimetres, and this can easily be accomplished without friction to the teeth by gradually moving the left forefinger forward.

This, in fact, constitutes laryngoscopia subglottica, and affords an opportunity of examining the subglottic space, the hinder wall of which can be sufficiently inspected by merely elevating the spatula sufficiently. It is particularly easy to get a view of the lower surface of the vocal cords if the spatula is inserted obliquely in the corner of the mouth. This will be dealt with farther on. Only in very rare cases can it be necessary to introduce small mirrors (which can, however, be easily done through the tube), though this might be useful in order to obtain a perpendicular view of the sinus Morgagni.

III. MISTAKES AND DIFFICULTIES.

Now that a particularly simple case in respect of suitability for autoscopy has been examined, it is time to consider the circumstances which render autoscopy difficult or impossible. These circumstances may be distinguished as being partly errors on the part of the surgeon or the patient, and, on the other hand, inherent difficulties from the peculiarities of the patient's organization. In such cases the ordinary method will require modification.

Mistakes.

I hope by an exact account of the method of producing anæsthesia and of the technique of ordinary examination, that the most elementary mistakes will be rendered impossible. I will, however, point out a few things which the beginner is apt to overlook.

In the first place it is useless to try and force examination when anæsthetics have not properly taken effect and the patient is coughing or choking. Absence of irritability is a primary necessity. If this cannot be attained at the first sitting, the patient should be invited to come again in the morning with an empty stomach. In the meantime a catarrh of the throat or epiglottis may be treated, and, if necessary, bromide or morphia administered before examination.

Excitement or fear on the part of the patient must be combated in the manner described before, especially if they cause him to strain or hold himself rigid. He should be told that, at the worst, he will feel an unpleasant, but quite bearable, pressure on the tongue, and that he must in any case go on breathing quietly, lightly, and regularly, even should he experience a purely subjective sensation of compression. Apart from the effect of cocaine, such sensations mostly depend upon reflex closure of the insensitive glottis. In very difficult cases it is as well at the first sitting to be content with a view of the arytenoid region, and to assure the patient that a useful view has been obtained, and that, when repeated, the examination will be completely successful.

The patient must be told not to bend his head back rigidly, but let it be in an easy and natural position. I have found on making careful measurements of pressure, that in the case of every patient the very best position for autoscopy is attained when the neck is gradually stretched more and more. Very frequently this most favourable position falls very far short of the complete degree of extension, in which position, indeed, the gullet is compressed by the lordotic curve of the vertebral column to a flat cleft with tense walls. For this reason it is advisable to allow the head to be bent back gradually at the second stage, until the most favourable position for autoscopy is found. The pressure should remain the same throughout and all alterations in the position of the head should be performed by the patient slowly. When an assistant is available, he alone should carry out the directions of the surgeon. A mistake which many patients make is shown in Fig. 32. In trying to avoid strong pressure on the tongue during autoscopic operation, patients slide forward on the seat and then take up a position with the body inclining backwards. In this position examination is almost impossible and the patient (and if necessary the assistant) should be previously instructed to maintain a sitting position with his back slightly curved. While making the examination the surgeon should, if possible, stand so as to prevent the patient advancing his knees. When the counter-pressure method is applied these difficulties do not occur.

It should be made a rule to reduce as much as possible the time during which the tube is inserted, and preferably to repeat the operation after a short interval. While the tube is in position the patient is not able to swallow accumulated saliva, and owing to his sitting position he cannot spit it out, so that it runs through the insensitive larynx into the trachea, and produces convulsive coughing.

I now come to mistakes made by the operator, of which the most frequent, in the case of beginners, is that of introducing the spatula too deep. When this is the case in the first stage, he cannot find the epiglottis until an accidental backward movement suddenly causes it to come into view. Again, when passing over the epiglottis, it is absolutely necessary to avoid pushing the spatula too far, because this would irritate the back wall of the pharynx, or the spatula might even get into the hypopharynx. There is practically never any difficulty in passing directly between the epiglottis and the back of the pharynx without touching the latter when a spatula with sloping end is used, whereas with bronchoscopes which have straight ends it is often necessary to work round laterally.

It is a mistake, in the second stage, to allow the tongue to be drawn out during autoscopic displacement, because this causes the tongue musculature to assume a state of contraction which is unfavourable to its displacement.

It is not necessary to make special mention of the advantage presented by gaps in the teeth. It is a more important question whether in the case of protruding incisors or lateral gaps the spatula should be introduced from the corner of the mouth. No general rule can, however, be laid down. Only so much is certain, that autoscopy from the corner of the mouth requires far more practice, and that normally, as I ascertained by a series of measurements, the autoscopic pressure is no less in this case than with the medial method of examination. This at first appears surprising, because the corner of the mouth can be more easily brought into line with the prolongation of the trachea than can the upper row of teeth. The reason is that, when the tube is placed laterally, pressure is not exerted on the middle of the tongue but nearer to its lateral attachment which is less yielding. This method is, therefore, only to be recommended in the special cases mentioned above.

The procedure in autoscopy from the corner of the mouth varies from the normal method only in the posture of the patient, who should bend and rotate his head slightly away from the side on which the tube is introduced (see Fig. 34).

Reference should be made here to a modification of autoscopy, already mentioned by Kirstein, in which the surgeon stands behind the patient (Fig. 35). I do not attach any particular value to this position, but in my "course" I always let students try it, because it forms an excellent preliminary to the most important introduction of the tube with the patient lying down. The unusual position of structures, which at first creates some difficulty in orientation, is exactly the same in both instances.

Direct laryngoscopy can, of course, be practised when the patient is lying down (*e.g.*, under an anæsthetic), but the sitting position is much easier for both surgeon and patient. The technique will be further touched upon when I come to bronchoscopy, in which, as opposed to autoscopy, the recumbent position plays an important part.

The next point is those difficulties in examination which are not due to errors on the part of the surgeon, and which are unavoidable.

Difficulties.

Apart from malformations, diseases of the cervical vertebræ and other pathological changes, the only unavoidable difficulty

PLATE IV.

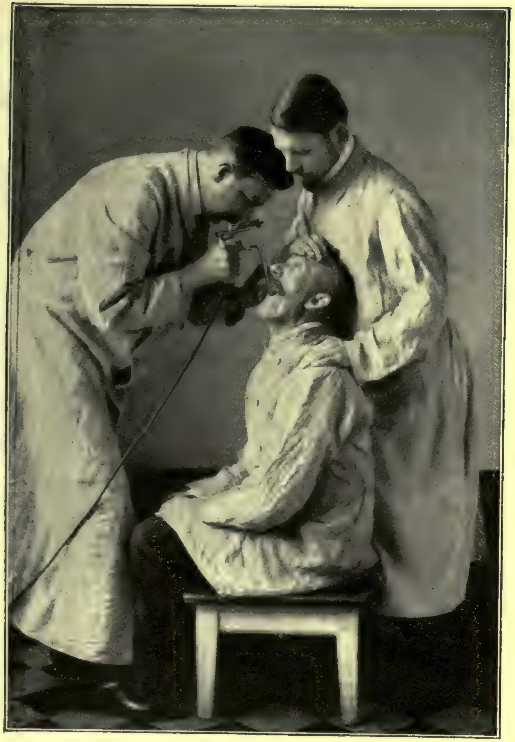


FIG. 34.—AUTOSCOPY FROM THE CORNER OF THE MOUTH.

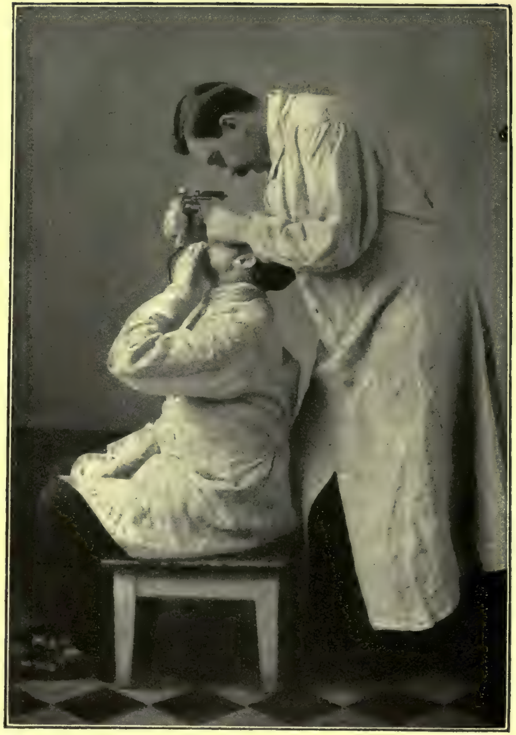


FIG. 35.—AUTOSCOPY FROM BEHIND.

To face page 106.

in direct laryngoscopy is the great individual variability of the facial skeleton, and of the soft parts about the floor of the mouth and of the neck. The condition of these often makes autoscopy more or less difficult, and, in extreme, cases impracticable.

In practice it is not the strength of the operator but the resisting power of the patient which must determine the limit to which the method can be applied. If the process is properly carried out, anæsthetics applied correctly, pressure on the teeth and extreme stretching of the neck avoided, the difficulty consists exclusively in unavoidable pressure on the tongue.

Owing to the extreme importance of this pressure, it is desirable to become well acquainted with its determing factors. For the study of this I have made use of a special contrivance —viz., "The Dynamometric Electroscope," in which by means of a gauged spring and a pointer the instrument indicates at any moment in kilogrammes the degree of displacing pressure exerted by the end of the spatula.

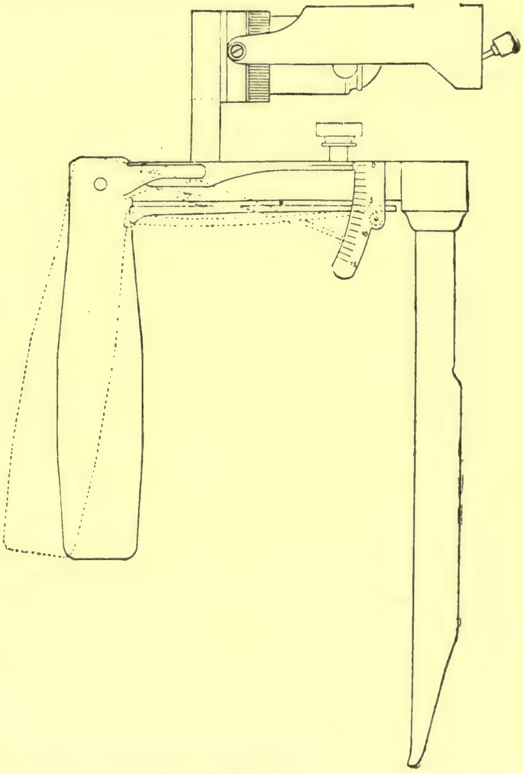


Fig. 36.—Dynamometric Handle. (After Brünings.)

The most interesting practical result arising from these experiments is the determination of the absolute degree of displacement pressure necessary for the presentation of the anterior commissure. It is not of much use to mention here a mean value, because individual variations are so great that the maximum may amount to thirty times the minimum.

With relative indications, 10 kilogrammes may be taken as the permissible limit, 15 kilogrammes must always be painful, and 20 kilogrammes constitute roughly the pressure which a man's hand can exert. The extraordinarily rapid increase of pressure in the progressive presentation from the posterior laryngeal wall (H) across the centre of the vocal cords (M) to the anterior commissure (V) should be noted. This is graphically represented in the following curve (Fig. 37).

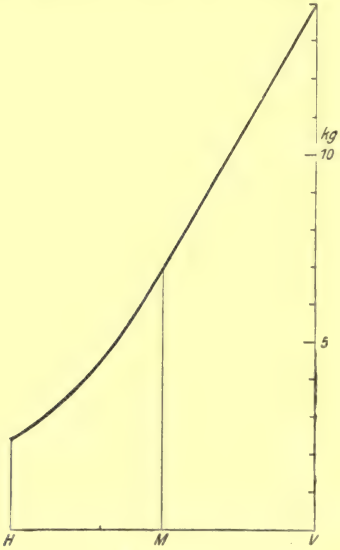


FIG. 37.

Among the non-anatomical and variable factors which have great influence on the pressure curve, anæsthesia must first be mentioned. According to its completeness, the degree of reflex muscular action of the patient, and consequently the conditions of pressure, is determined. A fact that is also of importance is that the patient acquires a certain familiarity with the examination, so that, when it is repeated, it is more easily performed than was the case at first.

By far the most variable factor, however, consists in the shape—*i.e.*, the breadth—of the spatula. It is well known that a narrow instrument can be pressed far into the extremely plastic root of the tongue, whose tissues readily fold round the sides of the instrument. If the surface of the spatula is broad, this is impossible, and the tongue can really only yield by dragging at its lateral attachments, and consequently no great amount of displacement is obtainable. For this reason the flat spatula which

Kirstein recommended for autoscopy is exceedingly unpractical, and it cannot fall short of a certain breadth without the field of vision being interfered with by the displaced portions of the tongue. If tubes either entirely or three-parts closed are used, such as my autoscopy spatula, there are no limits to the smallness of size.

I have shown in Fig. 38 what are the relative pressures and their effects with various diameters of the spatula. It will be seen that when the 9-millimetre tube is used a presentation of the anterior commissure is rendered possible with a pressure (9 kilogrammes) which, with the 14-millimetre spatula, scarcely brings into view the posterior wall. The figure also shows that, if it is desired to present only the posterior wall, a 14-millimetre spatula may be employed, provided the case is readily amenable to autoscopy. In all other cases the spatula should be thinner, in proportion to the intention to approach the anterior commissure.

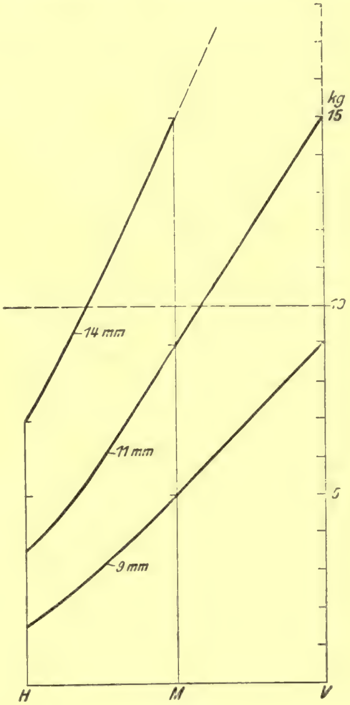


Fig. 38.

The terms "spatulæ for men" and "spatulæ for women," to distinguish between the 14-millimetre and the 12-millimetre instruments, are therefore quite erroneous, because, generally speaking, women can be more easily examined than muscular men. My case contains also spatula tubes of 8·5 and 7 millimetres, which in some cases may be very well used for autoscopy.

Unfortunately, the diminution of diameter in tubes very soon reaches a practical limit, because the rapidly decreasing extent of the field of vision interferes very much with the value of autoscopic diagnosis, and renders its operative application nearly impossible. I have consequently looked about for some other solution, and will speak of it in the next section.

IV. AUTOSCOPY BY COUNTER-PRESSURE.

The method of counter-pressure has for its object the diminution of autoscopic pressure, which, besides being an unavoidable inconvenience to the patient, limits the indications for direct laryngoscopy. Moreover, it renders possible the automatic continuation of the presentation of the larynx, and enables the operator to accomplish what has hitherto been impossible. As this method is important in practice, and is quite new, a somewhat complete account of it is desirable.

Explanations.

If the normal curve of autoscopic pressure (Fig. 37) is considered, the rapid rise of the section M—V, which in no wise corresponds with the progressive elasticity of organic tissues, is noticeable. There must therefore be some second factor at work in addition to the elastic resistance of the root of the tongue, which opposes itself to the gradual presentation of the larynx in proportion to increased pressure.

Exact measurements show that in all cases of autoscopy the larynx, and especially the prominentia laryngis, move forward by 0·5 to 1·5 centimetres, a movement which, in the main, coincides with the rapid increase of pressure from M—V. In reality, not only a dislocation of the entire larynx, but also a sagittal stretching and tension of the vocal cords is involved. For if the patient is made to emit a continuous sound while strong displacement is exerted, the note aimed at always turns out to be from a half to a whole tone too high.

The reason that the larynx yields to the autoscopic spatula is to be found in its firm ligamentous connection with the hyoid bone, which transmits the displacement of the root of the tongue to it. If, therefore, by some special means this movement of the larynx can be prevented, the last 5 to 15 millimetres of displacement of the tongue will be saved, and the great increase of pressure necessary to produce it will be avoided.

This auxiliary method can easily be so arranged that its application carries with it a further gain. By means of pressure in front exerted on the prominentia laryngis, the larynx can, without difficulty, be pushed from 5 to 10 millimetres farther back than the position which it normally occupies when the head is in the position required for direct laryngoscopy. If this displacement is added to the above, it must be possible, in specially favourable cases, to survey the entire larynx with a degree of autoscopic pressure which usually only brings into view the posterior wall.

Method of Procedure.

If the displacement necessary to bring into a straight line the angular passage between the upper row of teeth and the anterior commissure is remembered, it immediately becomes evident in what manner the counter-pressure can most advantageously be applied.

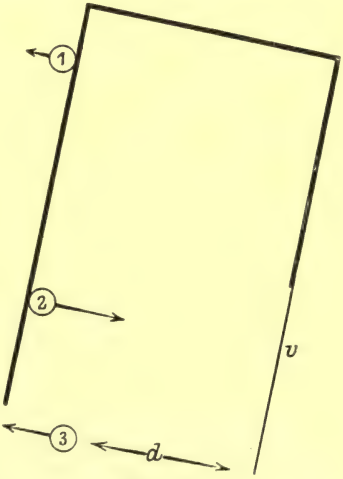


FIG. 39.

Fig. 39 represents graphically the three main features which are to be displaced (1, the teeth; 2, the root of the tongue; and 3, the larynx). The arrows show the direction in which displacement has to be effected. Now, if it is imagined that the counter-pressure at *d* operates on a prolongation of the electroscope handle *v* on the one hand, and on the other hand on the larynx (3), it becomes plain that not only 3 is pressed backwards, but 2 is also pressed forward, as desired, and 1 is pressed backwards—*i.e.*, through the counter-pressure the hand which holds the handle is relieved of work. At the same time the distribution of pressure, as indicated by the proportion of the lengths of the arrows, is favourable. One half acts forwards on 2, and the other half, which is directed backwards, is distributed between 3 and 1 in the proportion of the lever lengths 2 to 3 and 2 to 1, so that 3 receives about one-third, and 1 about one-sixth, of the entire pressure.

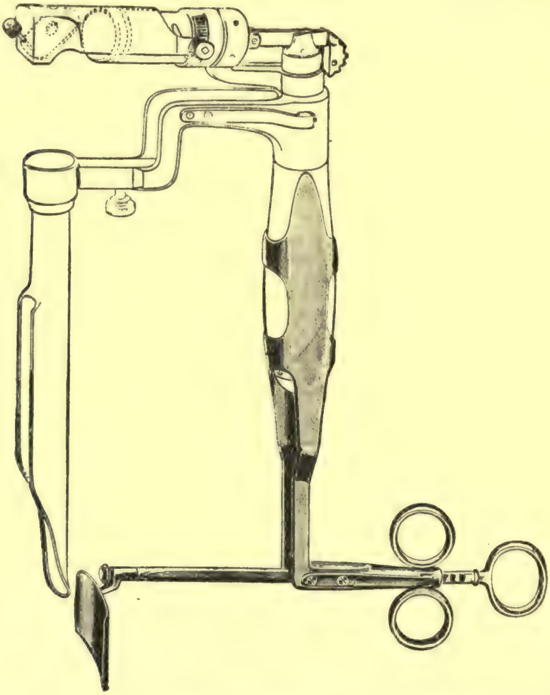


FIG. 40.—COUNTER-PRESSOR. (After Brünings.)

Fig. 42 shows how counter-pressure is practically carried out. The counter-pressure instrument consists of a pressure plate which can be moved forward with one hand by means of a rod and a three-ringed handle. By turning the small lever *a* (Fig. 41), an automatic stop is inserted which causes the pressure plate to remain in any position required. This simple arrangement can be attached directly to the electroscope by means of a light envelope, and admits of both the employment of the autoscopy spatula for adults and also of the spatula for children. In the latter case the pressure plate is simply turned upwards, so that its upper edge coincides with the end of the spatula.

The method of using the counter-pressure instrument is illustrated in Fig. 42, and, after what has been already said, requires no more explanation.

Employment and Advantages.

The beginner is advised to carry out his first autoscopic attempts without counter-pressure, in order that he may acquaint himself with the difficulties of the older method, and be able to judge what degrees of pressure are permissible; for with the help of the counter-pressure instrument a simple movement of the fingers enables him to exert an extraordinary force, for which at first he has no proper measure. If, indeed, autoscopy after Kirstein's plan is often a trial of strength on the part of the surgeon, so the counter-pressure method demands of him a corresponding sensitiveness of touch.

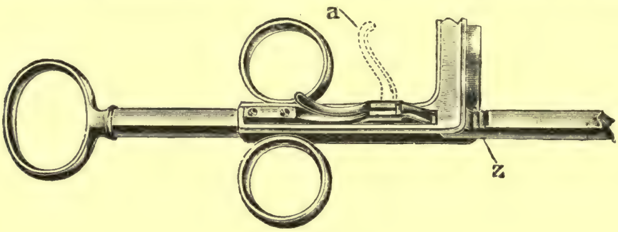


FIG. 41.

The use of the counter-pressure autoscope does not in the first place differ from the normal procedure previously described. In the first stage the pressure rod must, of course, be completely withdrawn, and, in the event of any difficulties of introduction, the pressure plate must be turned upwards. The second stage can only be carried out with some use of the counter-presser, which holds and directs the instrument. The beginner, however, is recommended to carry out the first part of autoscopic displacement without counter-pressure until the arytenoid cartilage is seen, and he has assured himself of the correct position of the spatula and knows how far to push it in, for only then will the pressure plate touch the right place—*i.e.*, the prominentia laryngis.

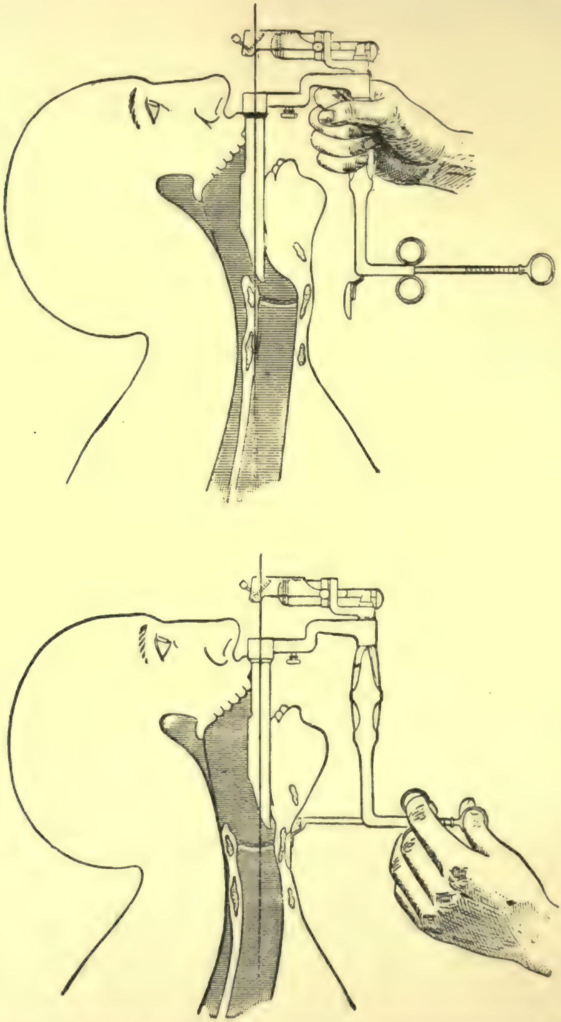


FIG. 42.—THE MODE OF ACTION OF THE COUNTER-PRESSURE METHOD.

PLATE V.

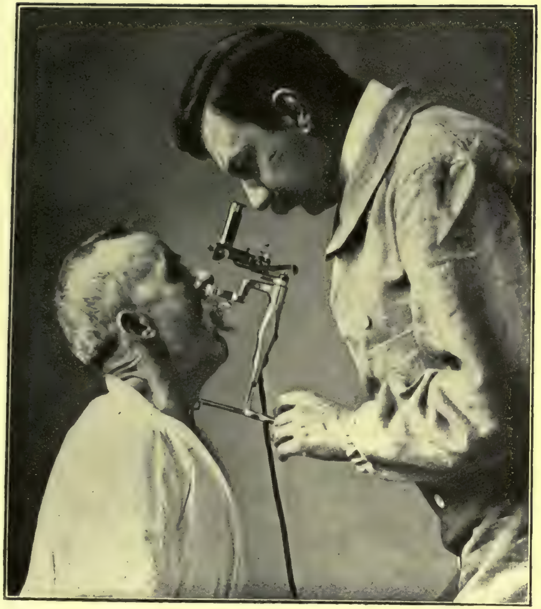


FIG. 43.—COUNTER-PRESSURE AUTOSCOPY (WITH TELESCOPE).

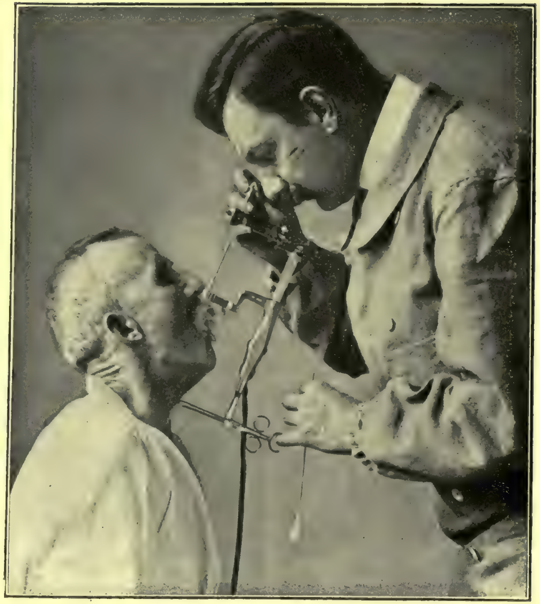


FIG. 44.—DIRECT OPERATION ON THE LARYNX BY MEANS OF COUNTER-PRESSURE AUTOSCOPY.

To face page 114.

It is obvious that all the rules applicable to the normal process of examination must also apply to the counter-pressure method. This applies also to the choice of a spatula of the right size, for the new method of examination is chiefly designed to make things pleasanter for the patient.

I must now mention the advantages of counter-pressure autoscopy, which are partly capable of being mathematically demonstrated. For if the examination is first carried out normally with the dynamometric electroscope, and the counter-pressure instrument then applied to its handle, a saving of pressure amounting to 40 to 60 per cent. will result. Only when much thicker spatulæ are employed is the same amount of pressure necessary as was previously required. This is a great alleviation for patients who are difficult to examine, since it is just the second half of the pressure which causes pain. In cases where autoscopy is easy of application, the field of vision is considerably enlarged, because in such cases it is possible to work with a larger tube.

It is an essential feature of the counter-pressure method that its advantages are greater in proportion to the desire to approach from the posterior laryngeal wall to the anterior commissure, and so inflict greater pressure of displacement on the individual. As regards indications for use, it follows that in very easy subjects the counter-pressure instrument may be used for operations, demonstrations, and lengthy procedures, and in moderate or difficult subjects it can be employed for brief diagnostic inspection. By this method I was able to remove a polypus situated on the anterior third of a man's vocal cord, although previously not even the posterior wall could be brought into view with an 8½ millimetre tube. As I had not before come across a case in Killian's clinic which was so little amenable to autoscopy, it might almost be said that with the counter-pressure method the applicability of autoscopy can be reckoned at 100 per cent.

I shall speak in the next section about the second great advantage of the counter-pressure autoscopy—*i.e.*, its operative applicability.

V. TECHNIQUE OF AUTOSCOPIC OPERATIONS.

A few months after the introduction of direct laryngoscopy, reports were made on the first laryngeal operations performed with this new method. Great hopes were held that autoscopy would introduce a new era of endolaryngeal therapeutics, because an organ which can be seen and reached directly has obviously a far better chance than if it is only visible as a reflected image in a mirror.

This hope has not been entirely fulfilled, and the reason for this, as Kirstein had already remarked, is found chiefly in the fact that it is difficult to employ autoscopy and to operate at the same time. As a rule, two hands are required to bring the larynx into view, and if the instrument is to be used, one hand only, and that the left one, has to do all the work. This being the case, it is impossible to avoid pressing painfully on the teeth, and this makes the patient restless and easily spoils the view. If it is also remembered that the delicacy and fineness of movement of the right hand is considerably interfered with by the left hand being exerted simultaneously, then it is not surprising that even practised users of the endoscope have hitherto preferred long curved forceps with the mirror to short straight instruments with the tube spatula.

Soon after the introduction of autoscopy, various attempts were made to construct a self-holding autoscopic spatula tube. For instance, von Eicken had short tracheal tubes made with lateral windows for use with Kirstein's hypopharynx tube, and by this means he was able to present that part of the larynx which he wished to operate upon. I myself have worked some time with my "beaked tube" (Fig. 93), a half-open autoscopy spatula with a bayonet-shaped end, which offers a support to the instrument in the throat without reducing the field of view. The beak tube has been very extensively used, and is of great practical utility for small operations in the posterior laryngeal wall, such as galvano caustic punctures. But it fails, like all other auxiliaries, in cases of operations on the vocal cords, more especially in the region of the anterior commissure.

The main obstacle to direct endolaryngeal surgical work is now overcome by the counter-pressure method. For, in addition to enlarging the field of view, it renders the presentation of the field of operation and the operation

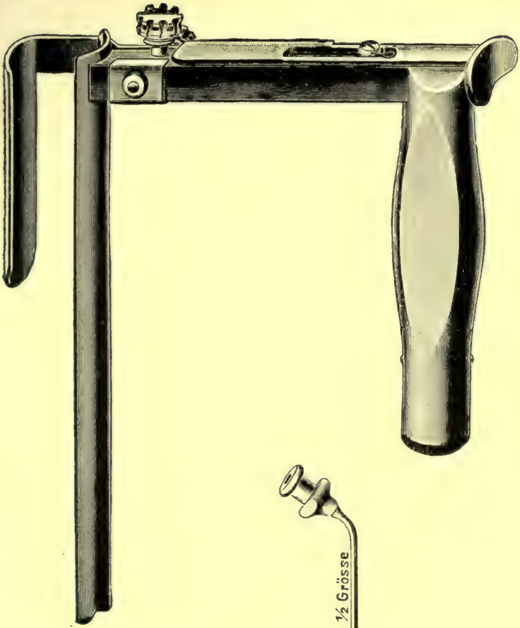


FIG. 45.—OPERATION AUTOSCOPE, WITH ATTACHMENT FOR COUNTER-PRESSOR. (After Brünings.)

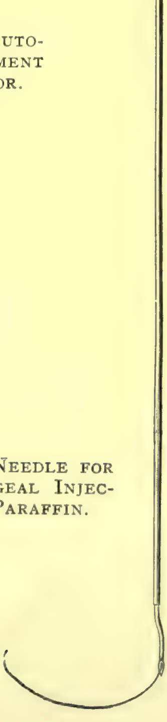


FIG. 45*a*.—NEEDLE FOR ENDOLARYNGEAL INJECTION OF PARAFFIN.

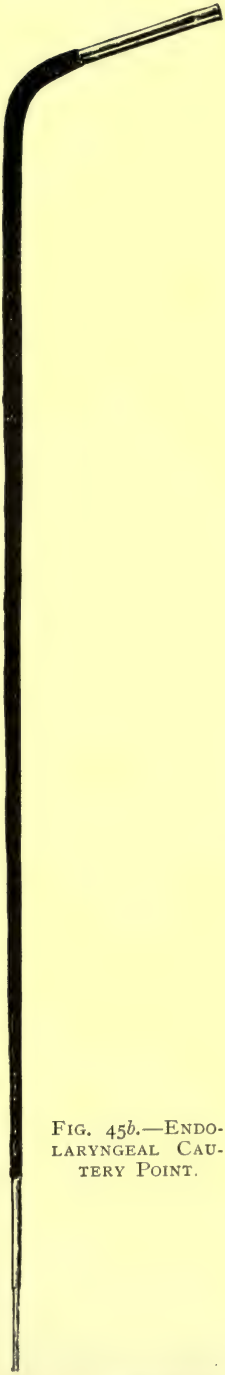


FIG. 45*b*.—ENDOLARYNGEAL CAUTERY POINT.

itself independent of each other, so that attention can be given to, and both hands used for, the latter.

In spite of this, there are still limitations to direct surgical work on the larynx, which I hoped in vain to overcome by means of a special operation autoscope (Fig. 45). These limitations arise from two characteristic features of tube examination. In the first place, it is impossible to exert any considerable degree of lateral pressure with the end of a long thin instrument introduced through a tube, because the shaft has not enough play in the narrow tube. Secondly, the movements of the instrument in the direction of the tube are apt to be uncertain, because of the difficulty of judging depth with one eye only. As will be seen later on, it is possible to place against these unavoidable disadvantages such important advantages that direct operations have become an indispensable adjunct to the indirect method. I am accustomed to do the greater number of laryngeal operations by means of the "counter-pressure" autoscope.

Foremost among the advantages is the immovable position of that part of the larynx which is presented in the tube, and the protection of the adjacent parts which is so desirable in cases where the galvano-cautery, local applications, or X rays, are used. In the case of the galvano-cautery, which I employ mainly for "deep puncture," as recommended by Grünwald,* counter-pressure enables the surgeon to make the puncture exactly perpendicular to the surface. As is well known, the majority of tuberculous infiltrations, in the treatment of which deep puncture is strongly indicated,† are found in the posterior part of the larynx in such a position that, by the indirect method, the instrument can only be applied in a more or less tangential direction. The cautery therefore always produces, apart from the uncertain depth of puncture, more extensive destruction of epithelium than when it is directed perpendicularly through the tube on to an operation field presented *en face*.

A cautery-point suitable for the method of procedure which has just been described has been made for me by Fischer (Fig. 45 *b*). Its free end is bent in bayonet form to enable the movements of the point to be exactly followed. As a rule, from one to two perpendicular punctures of from ½ to 1 centimetre in depth are sufficient at one sitting. The cautery is used at a dull red heat.

For the application of other caustics (trichloracetic acid, chromic acid), autoscopy also affords the advantage of complete immobility and the absolute protection of the adjacent parts. For this reason the treatment can not only be localized in the most exact manner, but can be allowed to act for a long time without the other side of the larynx being touched. By this means I often try to promote the cicatrization of tuberculous ulcers if lactic acid proves to be ineffective, and also employ it for the bases of non-malignant growths after their removal (papillomas, pachydermias).

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* Grünwald, *Die Therapie der Kehlkopftuberkulose*, München, bei I. F. Lehmann, 1907.

† Albrecht, *Ueber Kehlkopftuberkulose*, Wiesbaden, Bergmann, 1909.

I have written a detailed report elsewhere with regard to the direct autoscopic application of X rays.* I need only mention here that, in patients with tuberculous larynxes, I was only able to obtain a temporary effect with Röntgen rays.

Dilatation, Plastic Injections.

In the gradual progressive dilatation of laryngeal stenoses, the autoscopic method offers, in certain cases, advantages over indirect procedure. It is especially advantageous in the case of small children, where it is impossible to use the mirror, and where the surgeon has consequently been obliged, hitherto, to introduce the dilator by feeling. As it is a question of overcoming considerable resistance, "bougieing" is only free from danger when controlled by the eye, and this is rendered possible by the autoscopic method.

For the stenosis treatment of small children, which is usually undertaken only after a previous low tracheotomy, I employ English urethra catheters, from the smallest size up to about 10 millimetres (30 Charrière). The instrument is fitted with a stiff mandrin (either wire or a steel wool-carrier), and is then guided into the larynx, which has been previously cocainized; it is best to pass the catheter by the side of the tube as otherwise it interrupts the view. As the catheter is not easily bent, it is possible for considerable pressure to be exercised in a longitudinal direction. After overcoming the stenosis, the mandrin is drawn out, and the flexible catheter allowed to remain in position for an hour. A rubber tube drawn over the catheter protects it from being bitten. As soon as a certain "lumen" has been attained, the catheter can be passed "with half-autoscopy." By this I mean the prelaryngeal presentation of the epiglottis, which has been already fully described. If the lower 2 to 3 centimetres of the mandrin has been bent, it is easy then to carry the instrument under the accurate guidance of the eye round the epiglottis. In this way the larynx is readily entered, and a considerable pressure can be exerted.

By this process I have overcome almost complete stenoses of the larynx and of the subglottic space, although this only succeeds where the stenosis is very short or diaphragmatic in form. The treatment must be extended, with increasing intervals, over a period of one year or more.

In adults, autoscopic dilatation only comes into consideration for very narrow diaphragmatic stenoses, where the finest of the Schrötter catheters

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* "Autoskopische Behandlung der Kehlkopftuberkulose mit Röntgenstrahlen," *Zeitschr. d. Ohrenheilkunde*, etc., Bd. 62, 1911.

PLATE VII.

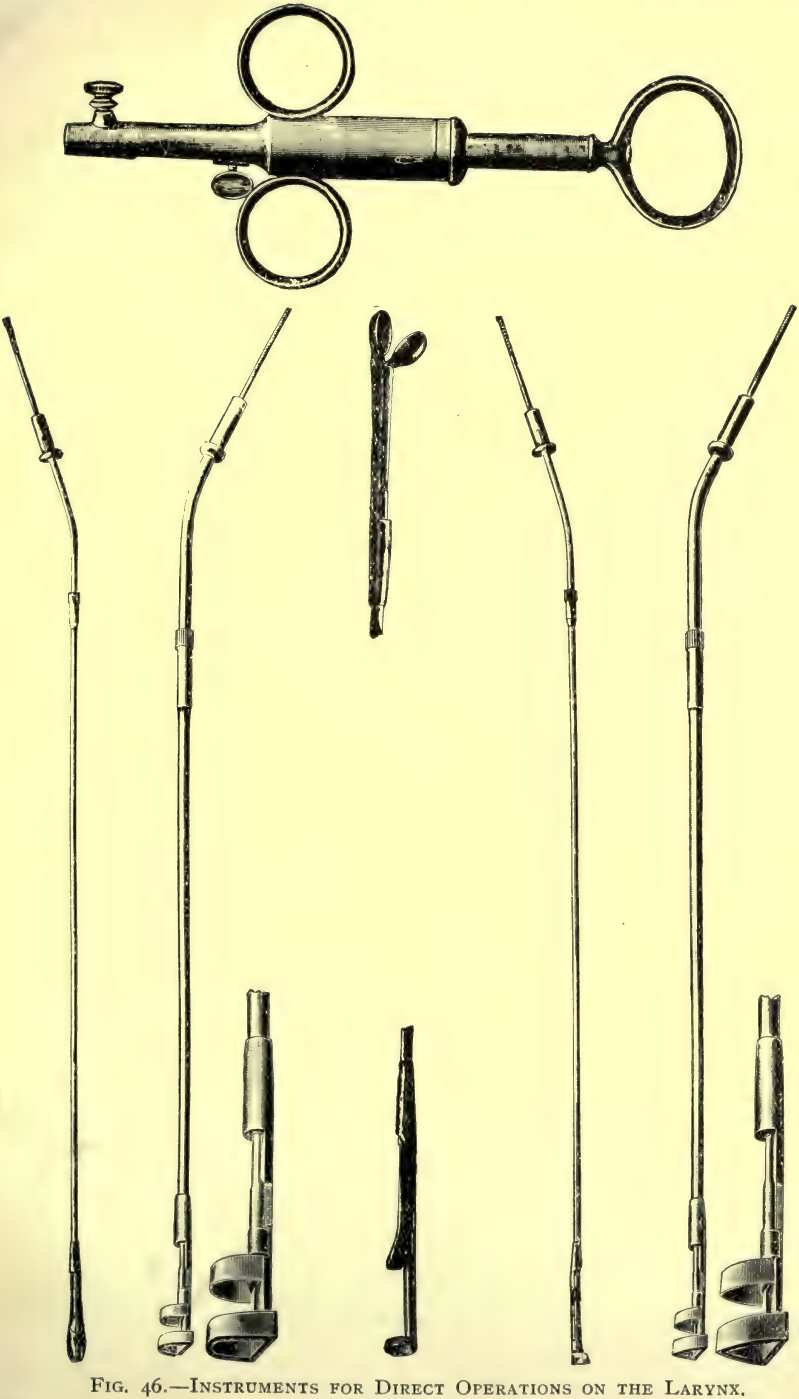

FIG. 46.—INSTRUMENTS FOR DIRECT OPERATIONS ON THE LARYNX. (After Brünings.)

is unable to pass. In the dilatation treatment of laryngeal stenoses due to scar tissue, I have never seen any improvement with fibrolysin.

It may be mentioned here that, in preoral intubation by the O'Dwyer and the Kuhnt method, "half-autoscopy" may occasionally be employed to advantage.

The endolaryngeal "plastic" with hard paraffin aims at achieving the direct opposite of dilatation—*i.e.*, at diminishing pathological widening of the larynx, which prevents proper closing of the glottis. Up to the present time I have only employed the method to overcome the phonetic and respiratory disturbances produced by one-sided recurrent paralysis, but have obtained such remarkable results that a short description of them may be given here.*

Disabilities which remain in the cases of old compensated one-sided recurrent paralyses are to be attributed to weakness and atrophy of the paralyzed vocal cord. This condition not only results in a defective closure of the glottis, and consequent incapability of energetic coughing, but leads to an excessive expenditure of air in speaking, so that the voice becomes weak and usually hoarse, and inclined to go into the falsetto. The pitch of the voice is also in most cases too high, owing to the compensating hypertrophy of the other vocal cord and of the strong innervation necessary for the overcrossing.

I have therefore made an attempt to restore the normal phonatory position to the limp atrophic vocal cord by means of injection of hard paraffin. As the vocal cord movements occur in a transverse direction, it was to be expected that the plastic might result, not only in a restoration of the respiratory closure of the glottis, but also in the removal of the phonatory disability.

The apparently difficult technique of the vocal cord plastic may be easily learnt with the help of counter-pressure autoscopy. For it I use one of the ordinary screw syringes for hard paraffin, on the end of which a canula about 18 centimetres long by 1 millimetre wide is fixed (Fig. 45*a*). At the end of this canula there is a fine, short, bent, bayonet-shaped needle soldered on. The syringe holds 2 c.c. of hard paraffin of 42° to 43° melting-point.

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* Brünings, "Eine neue Behandlungsmethode einseitiger Rekurrenslähmungen," *Verh. d. Vereins Deutscher Laryngologen*, Würzburg, 1911; *Verh. d. III. Internat. Laryngologenkongresses*, Berlin, 1911.

To carry out the plastic, the paralyzed side of the larynx is presented by means of counter-pressure autoscopy from the opposite side of the mouth, the lamp being in the high position. Injection is performed best, at the first sitting, in three places, the two outer of which are close to the anterior and posterior end of the vocal cord. The puncture should be made midway between the free edge of the vocal cord and its lateral limit. Each of these pieces receives about $\frac{1}{6}$ to $\frac{1}{4}$ c.c. of hard paraffin, according to the varying individual circumstances. The assistant who is checking the screw syringe should count the revolutions aloud in order to be able to reckon the injected dose accordingly.

The determination of the proper depth of puncture offers no very great difficulties. If the puncture is too deep, the paraffin is seen at once in the subglottic space. The needle is then slowly drawn back during the further injection, in order to distribute the paraffin over the whole thickness of the vocal cord. The fear, also, lest the injection might produce separate protuberances at three places has proved to be groundless, as the intervening spaces are apparently equalized by means of reactive cellular activity.

I have never seen any considerable degree of œdema after the injection, but it is well to make the patient spare the voice for two or three days. After this, phonation exercises should be commenced with as deep a voice as possible, and with all possible economy in using the expired air. Slight inflammatory reactions, which may occur in the first days, produce no disturbance. I have up to the present time treated seven patients by this new method, and as most of the cases were of old standing (half to two years), the maximum atrophy had set in, and spontaneous improvement was no longer to be expected. The result was in three cases quite surprising, and the respiratory disturbances were also completely removed in the four other cases. The patients were able in a few days after the injection to speak and cough in a normal manner, and the voice weakness and the phonatory expenditure of air had improved even to the point of completely disappearing. On the other hand, the voice acquired a strong but, in singing, a somewhat rough sound. In each case the patients were entirely satisfied with the result of the treatment. It seems advisable, according to present experience, not to inject more than $\frac{1}{2}$ c.c. Should the correction be found to be still insufficient after eight days—that is to say, should the vocal cord not be in the median line—a second injection may be made.

With regard to the duration of the results, I am unable at present to judge; my longest-standing case has remained without change for more than half a year. It is possible, according to results which have been obtained otherwise with paraffin plastic, that the injection would require to be repeated after some years.

Hitherto I have only performed the injections in a direct manner, and they offer no difficulties in cases where the conditions of autoscopy are not too unfavourable. The indirect procedure would here be extremely uncertain.

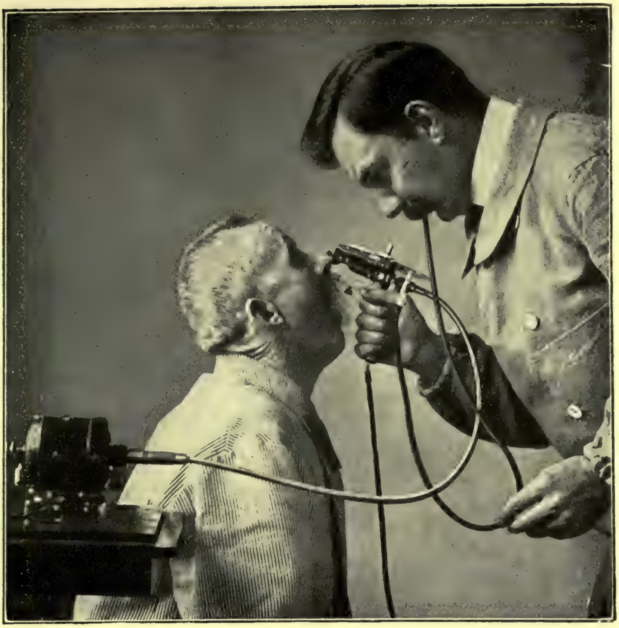

FIG. 47.—DIRECT STROBO-LARYNGOSCOPY.

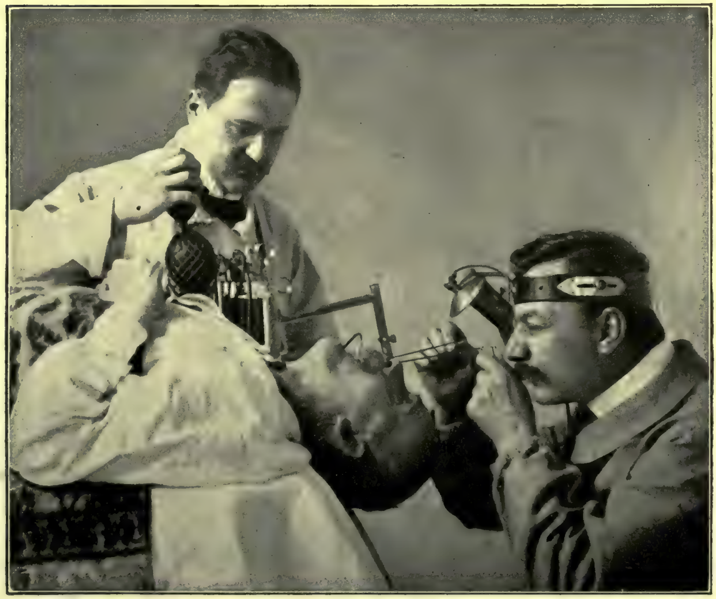

FIG. 48.—DIRECT OPERATION ON LARYNX (WITH GENERAL ANÆSTHESIA AND COUNTER-PRESSURE AUTOSCOPY).

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Operations which cause Bleeding—Foreign Bodies.

Operations such as incisions, curetting, removal of growths, etc., are confined within limits similar to those of the indirect method, and the operating instruments can therefore be made on the same principles. In Fig. 46 a few sharp "double spoons" and punches are represented which can be affixed to a three-ringed handle. The construction is carried out in such a manner that the end of the forceps does not move when closing. By means of a fixing screw inserted in the shaft, the instrument can be used at any angle, which is absolutely necessary with direct operations. The length of the shaft up to the bend must be about 18 centimetres, so that the instrument may be moved with perfect freedom with the lamp high. The instruments which I use most frequently are the double spoon and the smallest punch shown in Fig. 45. The larger punches can only be used with the wide 14-millimetre autoscope spatula, the use of which is limited to cases which are readily amenable to autoscopy.

Indications for direct laryngeal operations depend largely upon the preference of the surgeon—*i.e.*, whether his experience lies in the direct or the indirect method, because most cases may be treated either way. Nevertheless there are some cases in which autoscopy is the only possible method. Foremost among such operations are those cases of children where the mirror cannot be used, and these belong to the most difficult class of autoscopy. Surgeons who are accustomed to the use of the Kirstein lamp can use it with advantage in autoscopic operations on children, as the illumination is usually sufficient with a short, wide spatula.

In addition to children, there are some adults who cannot be treated with the mirror or are unable to be kept quiet. I have had to treat several patients of this kind, where the use of the mirror was not tolerated, though small manipulations could be carried out autoscopically with the greatest ease.

Among cases which are beyond the scope of these indications, I must mention operations in situations difficult of access, such as removals on the under-surface of the vocal cords, in the subglottic space, and on the posterior wall of the larynx.

The autoscopic method is of special importance for the treatment of foreign bodies, inasmuch as these, in the majority of cases, occur in children. Direct laryngoscopy not only allows the foreign body to be accurately presented with the greatest clearness, but enables it to be loosened by suitable displacements of the end of the spatula, and so brought into the required position for extraction. Lastly, the use of straight extraction instruments renders possible rotatory movements round the long axis, and without these the loosening of firmly impacted foreign bodies cannot be carried out. A thorough cocaine treatment of the area of the operation is essential in the case of every foreign body.

CHAPTER IV

TRACHEA AND BRONCHIAL TREE

No special justification seems necessary for writing this chapter to summarize those properties of the object of investigation which are important for the tracheo-bronchoscopic method, before entering on the method itself, because such general knowledge can scarcely be presupposed as in the case of direct laryngoscopy. Indeed, such knowledge is very difficult to acquire, as it can, in part, only be obtained by the application of the method itself. In order to avoid repetitions, I am therefore compelled, for the present, to limit myself to the outward inspection of the bronchial tree, which will be considered first. The endoscopic picture, which is the ultimate aim of the examination, will be discussed later on in connection with that inspection. The phenomena of movement which are endoscopically visible are excepted, because the discussion of them would interrupt the description of the normal course of the examination.

In dividing the subject, a distinction must clearly be made between anatomy and physiology, and it must be remembered that only such morphological and functional properties as possess immediate value for the method of investigation are germane to the discussion.

I. ANATOMICAL.

A knowledge of the form, situation, and relative sizes, of the object of the examination is of the utmost importance. There are, unfortunately, great difficulties in the way of ascertaining these data accurately, and so the literature* on the subject presents a number of irreconcilable statements which cannot be explained by actual variations in the organs themselves, great as these certainly are. It has, indeed, been stated† that measurements of the tracheo-bronchial tree made on dead bodies yield quite erroneous results, because during quiet breathing the living trachea is believed to be in a constant state of contraction, so that the posterior ends of the tracheal cartilages, as well as the edges of the two neighbouring cartilages, touch each other. That this observation, made on dogs, is erroneous, at least so far as human beings are concerned, may be shown by any endoscopic examination. Moreover, in the trachea and bronchi there are no longitudinal muscles whatever.

No doubt the method of preparation plays an important part in the representation of the tracheo-bronchial tree, as considerable changes of shape occur both in preparations made after the pleura has been opened and also when metallic solutions are employed. At least I believe that the typical departures of such pictures from my skiagrams are to be explained by the dragging effect of a heavy metal, which is poured in and stiffens while the body is in a more or less upright position.

I was therefore obliged to rely on my own investigations, and found that skiagrams afforded the best

Method of Representation

for this purpose, especially when a comprehensive picture or a topographical projection on the wall of the thorax is required. The latter is extremely important for the question in hand, and the literature on the subject says nothing to the point. Skiagrams of the tracheal tree have hitherto suffered from many inherent defects, so that it has been necessary to elaborate a new procedure. The experiments were made in conjunction with my colleague M. Weingartner, with the approval of Herr Bäumler, in the Röntgen Laboratory of the Medical Clinic. A few words are necessary in order to understand the pictures, especially as the procedure illustrates the employment of bronchoscopy and is not only interesting from the point of view of skiagraphy but also from that of diagnosis.

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* *Cf.* Aeby, "Der Bronchialbaum der Säugetiere u. des Menschen," Leipsig, 1880; Jössel u. Waldeyer, "Lehrbuch der topographischen Anatomie," Bonn, 1899, Bd. 2; Merkel, "Handbuch der topographischen Anatomie," Braunschweig, 1899. Further references to the literature of the Trachea are found in Wild, *Beiträge z. Klin. Chirurg.*, Bd. 45, 1905, and in Przeworski, *Arch. für Laryngol.*, Bd. 8, 1898.

† Lejars, "La forme et le calibre physiologiques de la Trachée," *Rev. de Chirurg.*, 1891.

Skiagrams in living subjects show but little of the bronchial tree. It is true that the so-called hilus markings are not yet clearly understood, but little use of them can be made for explaining the course of the bronchi, even if they are regarded as negative air shadows as De la Camp* shows to be very probable in his excellent experimental skiagrams. The picture of the cervical part of the trachea is very clear, but is soon lost in the thorax in consequence of the strong mediastinal shadow caused by the superimposed tissues, so that the position of the bifurcation is rarely and only very doubtfully indicated. Pfeifer† certainly succeeded several times in obtaining particularly beautiful skiagrams in which the branching of the principal bronchi could be distinguished, but this is quite exceptional.

Various skiagrams of the injected tracheo-bronchial tree have been prepared from investigations on dead subjects. The value of such pictures depends entirely on the way they are taken and on the method of injection. If, for instance, heavy emulsions are employed instead of the easily melted metallic alloys, whose drawbacks have already been mentioned, considerable difficulties may be encountered. If the body is in an upright position, there is a great danger that the fluid may run into the alveoli, and the whole lung be solidified to an opaque mass; whilst if the body is in a sloping or horizontal position, it is difficult to make sure that those branches which run in an upward direction are properly filled. In addition to this it must be remembered that heavy emulsions quickly form sediments, and that it is very difficult to obtain a clear orthoscopic presentation when the body is in an oblique position.

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* "Das anatomische Substrat der sog. Hiluszeichuung im Röntgenbild," *Physikalisch-Medizinische Monatshefte*, 1904, Heft 7.

† "Die Darstellung der Trachea im Röntgenbild," Beiträge 2, *Klin. Chirurgie*, Bd. 45, 1905.

The latter point certainly has hitherto received no attention whatever, as, owing to the usual small distance of the tube, there can be no question at all of orthoscopy. Like all skiagrams taken at close quarters, these pictures are, with the exception of a small central region, projected so centrally as to be of little value for topographic studies and measurements. Owing to the gradual stiffening, any effect of pressure such as is apt to occur in long columns of liquid is certain to be avoided, and the corpse can be placed horizontally before being skiagraphed. The bronchi then return to their normal positions, unhindered by the extremely elastic gelatine injection.

After making sure that a skiagram could be taken of the tracheo-bronchial tree in its undisturbed form, it was further necessary to employ a mode of representation which would yield an orthoscopic projection as free as possible from markings, but which at the same time would represent plastically dimensions in depth. This can be done only by a combination of radio-stereography with orthoscopic photography from a distance, and this process I call "ortho-stereo-radiography."

It would lead too far at the moment to discuss this method of representation theoretically but this will be done elsewhere.

The principle of it is to make the interval between the anticathode and the plate at least ten times as large as the greatest interval between those points of the object represented which is to be represented orthoscopically. In order to obtain a proportionate plastic picture, the length of the stereoscopic basis must, of course, be increased in the same proportion as the distance of the object. I have taken as a basis for all photographs the proportion 1 to 10, which gives a somewhat greater plasticity than binocular views from the same distance.

In the thorax of adults, the anticathodal interval, as a rule, amounted to 200 centimetres, and the stereoscopic displacement to 20 centimetres. A pendulum was used, and the exact point of the bifurcation of the trachea or of the sternal end of the second rib was presented. The projection of the bifurcation may be regarded as practically accurate, but the diameter of the trachea is increased by 1 to 2 millimetres. The greatest correction is required for the interval between the larynx and the bifurcation, as in adults this is from 8 to 10 millimetres too big. For the subsequent measurement of relative proportions I have constructed a scale which is visible radiographically, and which was in every case photographed at the same time. It also shows the relative reductions of the figures.

I have described the principles of this new method in order to show that these skiagrams (with the corrections mentioned), in contradistinction to the usual skiagrams, can be utilized for measurements. The ortho-stereo-radiographic process, in conjunction with the bronchoscopic injection of gelatine into the cadaver, is of great value in other ways, and is the only aid in the study of pathological changes in the tracheo-bronchial tree, such as diseases of the trachea or of the lung or neighbouring organs. As Ewald has already stated, there is not as yet a method for the autoscopic proof of deviations, curvatures, and stenoses of the trachea and the bronchial tree which can lay claim to anything like accuracy. Indeed, the great variety of discoveries is generally lost when the usual procedure is adopted (which is in no way interfered with by the gelatine injection, which is easily removed). I have added, by way of illustration, two radiograms of pathological cases, and hope that I shall soon be able to illustrate the subject from more extensive material.

Relative Forms.

The tracheo-bronchial tree has the general form of an inverse **Y**. The situation of the middle limb, the trachea, is not exactly in the median line, but deviates in its lower portion towards the dorsum, generally more or less to the right (compare radiograms, Figs. 51-55).

This deviation is caused by the arch of the aorta, which curves round the left main bronchus and passes close along the left tracheal wall (see Fig. 49). The form of the trachea is seldom absolutely straight, even when the body is held straight, and varying positions generally cause it to assume a variable and slightly **S**-shaped curve (see Figs. 53 and 54).

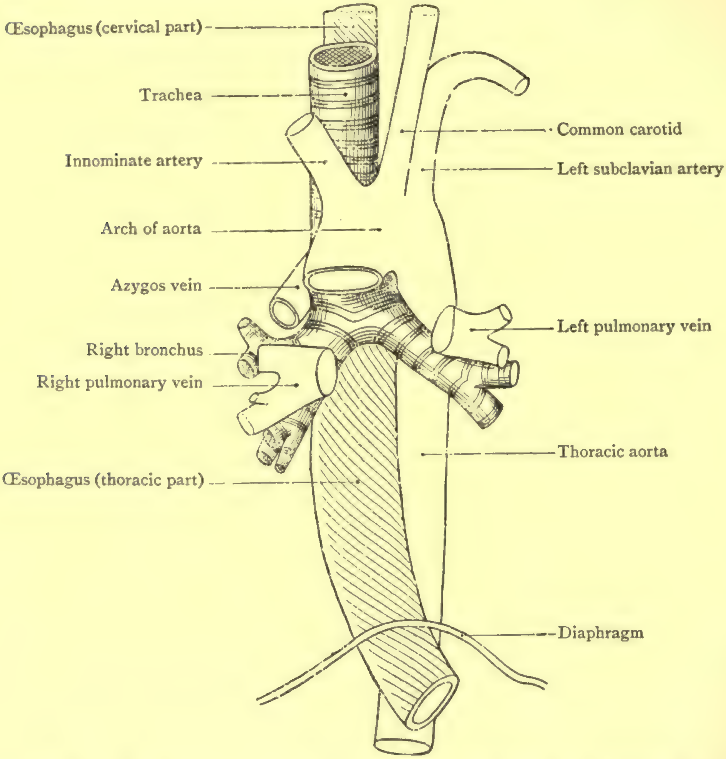

Fig. 49.—Relations of the Trachea to the Œsophagus and Great Vessels.

The diameter of the trachea, the middle section of which is somewhat horseshoe-shaped owing to the cartilaginous rings being open in their posterior third, does not vary much at different levels. If, for the present purpose, the rima glottidis or the plica vocalis is taken as the commencement of the lumen, it will be found to be compressed laterally at this point (see Figs. 51, 53, 54); while lower down in the subglottic space, broadening like a wedge, it gradually assumes a more circular section, and so attains its full width. In the sagittal direction, the diameter of the subglottic space and of the rima glottidis frequently exceeds even the average diameter of the trachea, so that the circumference in that region, together with its elasticity, allows of the introduction of round tubes whose diameter greatly exceeds the transverse diameter of the trachea at this point.

Normally (Fig. 51) the lumen of the trachea only increases slightly in its middle portion, but considerable enlargements may be produced by pathological conditions. According to Przeworski,* such dilatations are the rule in chronic coughs (bronchitis, emphysema, phthisis). They only affect the paries membranacea, which when filled with water bulges and presents a sacculated appearance (compare the skiagram, Fig. 54).

The bifurcatio tracheæ divides the trachea into two branches, the right and the left main bronchus, which enter the roots of the lungs at different acute angles. The constant displacement of the bifurcation to the right causes the right main bronchus to deviate less than the left from the direction of the trachea. It is clear from Figs. 51, 53 and 54, that the right bronchus coincides the more closely with the prolongation of the trachea the more the bifurcation is displaced. The same cause explains the sharper angle that the left main bronchus makes, which in extreme cases may be so great as almost to make it look like an unpaired branch of the trachea.

The angle of bifurcation made by the two main bronchi seldom amounts to 90°. Very extensive variations occur here, and in the cases examined it appeared to be the rule that the angle is larger in proportion to the breadth and shortness of the neck and thorax (compare the difference between Fig. 51 and Fig. 54). The mean values given, according to which the angle of the right main bronchus with the trachea is about 25° and that of the left about 45°, are, therefore, of no importance.

The extramedian position of the bifurcation ridge in relation

* "Über die Divertikal der Trachea," *Arch. f. Laryngologie*, Bd. 7, 1898.

to the lumen of the trachea has an important bearing on endoscopic investigation. Obviously it must be displaced to the left in proportion as the left main bronchus deviates from the direction of the trachea. It hardly ever assumes an exactly median position, because the greater width of the right main bronchus of itself implies a noticeable deviation.

The greater diameter of the right main bronchus is just as constant as the excess of the two bronchial lumina together over the lumen of the trachea. The bronchial branches are divided on such a plan as to suggest a tendency to counteract increased atmospheric resistance, occasioned by increased surface friction, by a gradual increase of the total transverse section of a given region of ramification.

The subdivision of the two main bronchi conforms to a fairly regular type. In the first place, the two upper lobes of the lungs, right and left, are each supplied by an upper lobe bronchus (R.O.B., L.O.B., Fig. 50; compare the ortho-stereo-Röntgenogram, Fig. 52). The main direction of these two branches is lateral, corresponding to the lateral situation of the lobes of the lungs; but they also run somewhat ventrally (compare the stereogram), and generally the number and development of the forward branches is predominant, in consequence of the situation of the bronchial tree being mainly dorsal.

The cephalic position of that part of the lung served by the upper lobe bronchus causes its stem to be directed more or less horizontally, and frequently even somewhat cephalwards. Here the rule (which is shown on the stereogram) is again exemplified—viz., that in all bronchial branches the angles of division are greater in proportion as they belong to higher sections of the lungs.

The variation in the point of origin of the upper lobe bronchi is of practical importance, as from it results a great difference in length of the two bronchi. These differences are brought about by the different position of the two branches with reference to the pulmonary artery. The right bronchus passes above the artery (eparterial) to the hilus of the lung, while the left (as with all other branches) passes below the artery (hyparterial). (In Fig. 49 only the venæ pulmonales are shown.) The level of origin of the upper lobe bronchi is pretty variable; the right one, especially, may rise at the level of the bifurcation spur (see Fig. 55), and in abnormal cases even from the trachea itself.

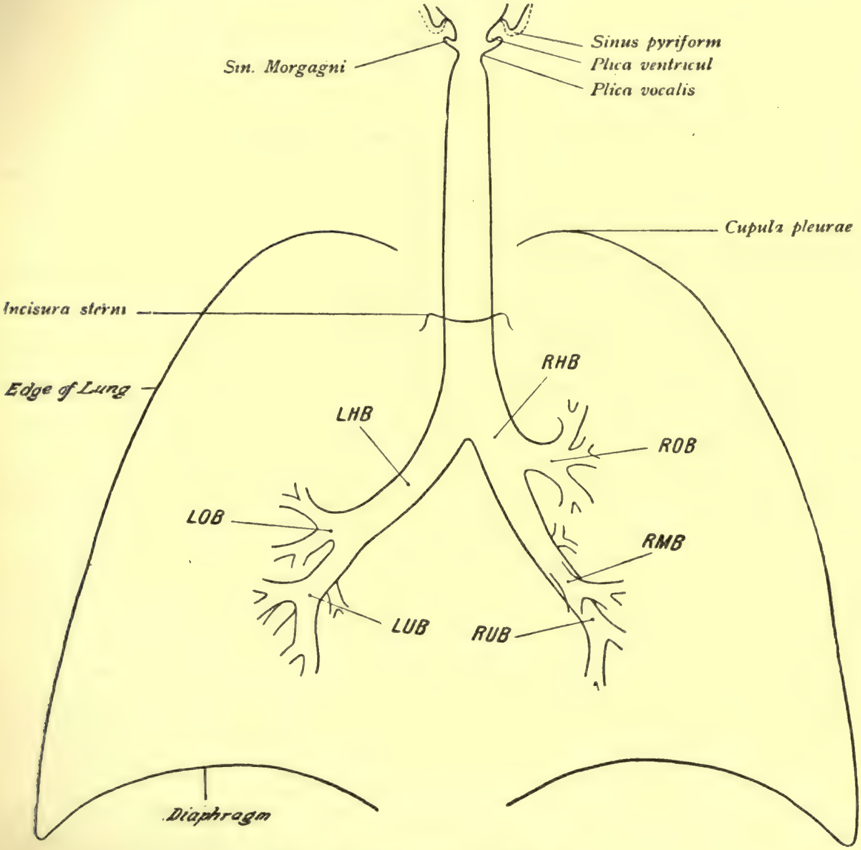

FIG. 50.—DIAGRAM OF FIG. 51.

The continuation of the right and left main bronchus, after the exit of the upper lobe branches, is known as the "trunk bronchus,"* and the right one is considerably longer than the left. This follows from what has just been said. The trunk bronchi rapidly diminish in calibre, after giving off ventral and dorsal lateral bronchi, and their more or less rectilineal direction may be followed as far as the posterior part of the bases of the lung.

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* Other authorities designate the main bronchus lower lobe branch as the trunk bronchus, and this is again divided into an upper (eparterial) and lower (hyparterial) section.

For the localization of foreign bodies, it is important to remember that the decrease of lumen take place abruptly at certain intervals, and the portion situated between two such points has a more or less cylindrical form.

Of the lateral bronchi, the right middle lobe bronchus (Fig. 50, R.M.B.) is constant, the direction of its origin being purely ventral. That portion of the trunk bronchus which is situated below it may be termed the "lower lobe branch" (R.U.B.), in so far as it supplies the right lower lobe by its numerous divisions. On the left side there is no middle lobe bronchus corresponding to the lobe of the lungs, and so the lower lobe branch (L.U.B.)—part of the trunk bronchus—has a much wider ramification. It is important to notice that, in addition to these regular lateral bronchi, a number of inconstant ventral and dorsal branches may arise, only two of which appear in Fig. 50.

The finer ramification of the trachea (compare Stereogram 52), which in contradistinction to the bifurcation has generally the monopodic type, is of no direct bronchoscopic interest, but the bronchial skeleton—*i.e.*, the cartilaginous rings, must be mentioned. In the trachea their number varies from sixteen to twenty. They are open in the posterior third, and seldom connected by irregular bridges. In the main bronchi, which are exactly like the trachea in structure, the right has from six to eight, and the left from nine to twelve cartilaginous rings, which are also open behind. The trunk bronchi are only provided with irregular cartilaginous plates which often coalesce and are scattered over the whole periphery. Their thickness constantly decreases, until in tubes of 1 millimetre they are completely absent. I shall have occasion to speak of their elasticity and resistance later on.

PLATE IX.

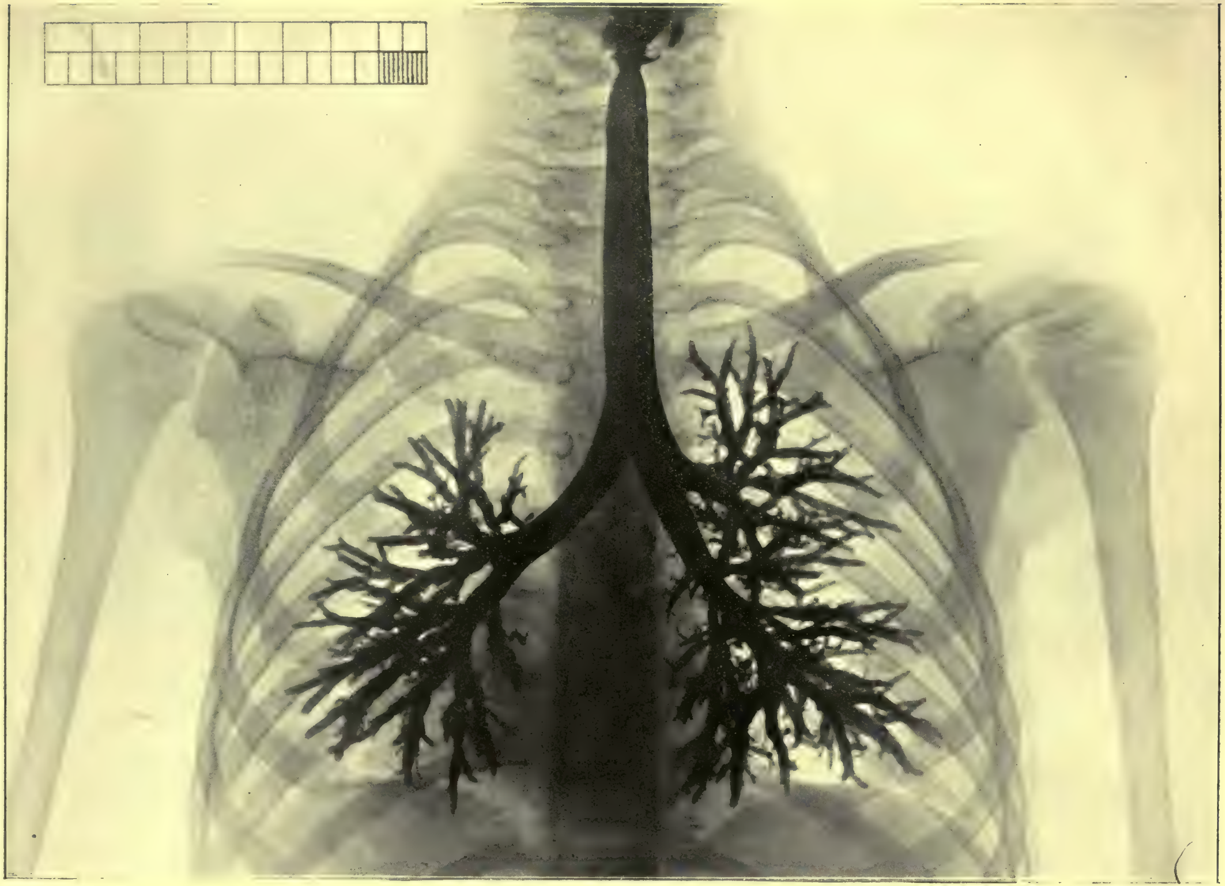

FIG. 51 —ORTHOGRAPHIC REPRESENTATION OF THE NORMAL BRONCHIAL TREE (TWELVE-YEAR-OLD GIRL).

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PLATE X

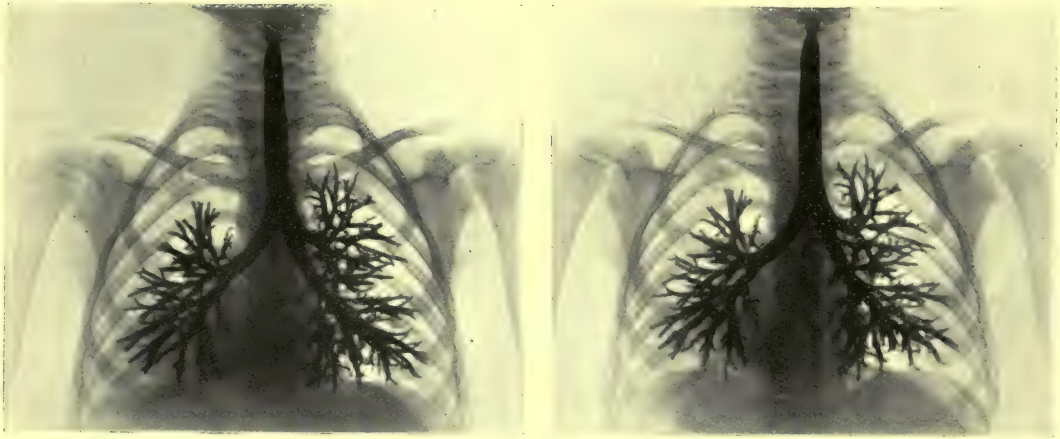

Fig. 52.—Orthostereogram of the Bronchial Tree.

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PLATE XI.

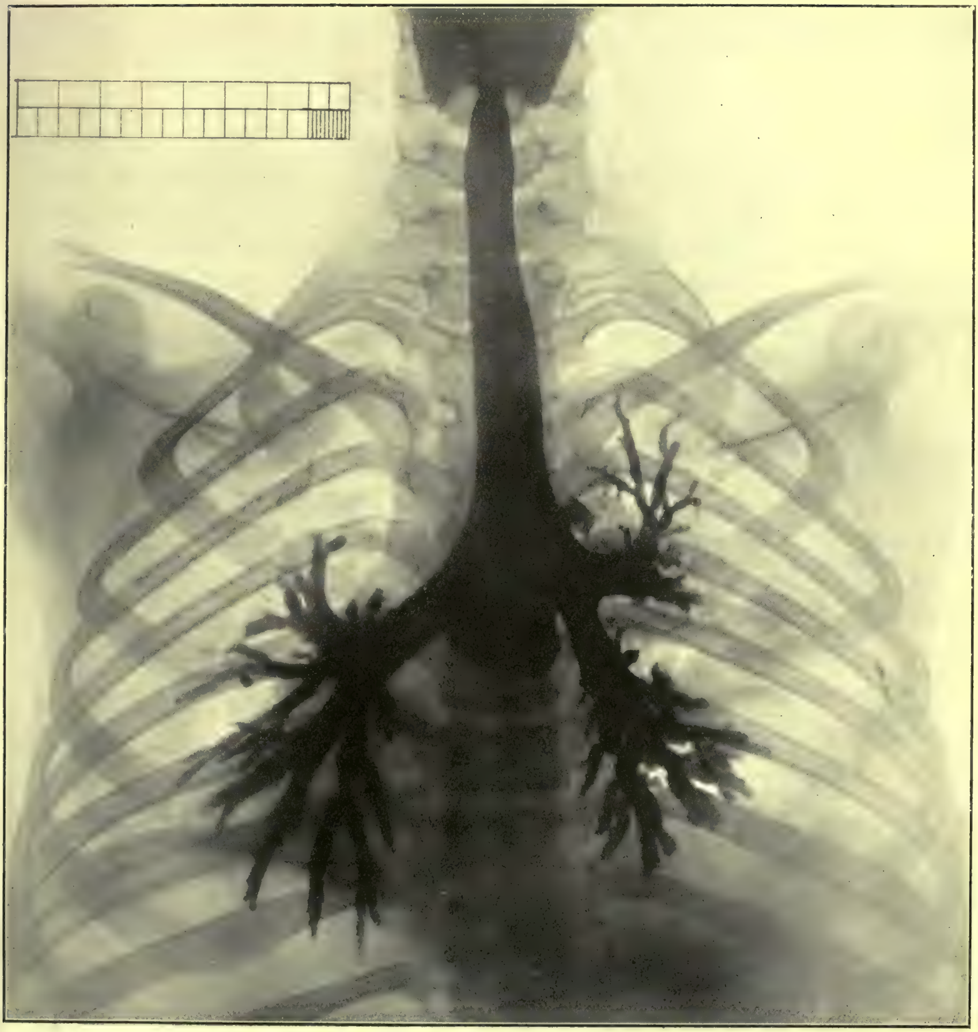

Fig 53.—Orthographic Representation showing Tuberculosis of the Lymphatic Glands at the Bifurcation of the Trachea (Sixteen-year-old Girl).

To face page 132.

Relations.

With regard to the relations of the trachea, it has been said already that in the upper part its posterior membranous wall immediately touches the œsophagus. Lower down, as has been shown in the injection skiagram, this generally deviates somewhat to the left (in other words, the trachea deviates to the right), so that the sketch given in Fig. 49 must in this respect be regarded as exceptional.

The position of the bifurcation as regards the thoracic wall is very important from a diagnostic and operative point of view (interpretation of skiagram), because if its position is familiar it is possible to trace the course of the main bronchi with considerable exactness. In topographical anatomy books it is generally stated that the position of the bifurcation in front corresponds with the sternal end of the second costal cartilage, and behind with the spinous process of the fourth dorsal vertebra. In the case of children the numbers would be three and five respectively. I am not quite able to confirm these data from teleskiagrams, orthodiagrams, and tracheograms (see farther on).

In the case of the skiagrams (the dead body being absolutely horizontal, and the picture taken from a distance of 200 centimetres), the bifurcation in the case of a twelve-year-old girl (compare the stereogram) is situated at the lower edge of the first sterno-costal articulation, in the case of a new-born child (Fig. 53) halfway between the first and second. In a sixteen-year-old girl (Fig. 53) it approaches the upper edge of the second sterno-costal articulation, and in the case of an adult (Fig. 54) it coincides with it. It will be seen that in the orthodiagrams (which were made with the large Grödel orthodiagraph in an upright sitting position, after injection of mercury) the bifurcation in Fig. 56 touches the upper edge of the third rib; in the case of an old man it coincides with it. The latter is also the case in the two direct tracheograms (Figs. 77 and 79).

From these various facts it may be assumed that with increasing age the bifurcation falls lower, in consequence of the fall of the entire contents of the chest. This also agrees with the statements of Mehnert.* If to this is added the fact that the vertical position of the sternum differs in different subjects to the extent of several centimetres, it is obvious that the perpendicular projection of the bifurcation may vary between the sternal ends of the first and third ribs.

The practical use to be derived from other topographical relations likewise presents difficulties. I have found from skiagrams that the length of the trachea from the level of the vocal cords to the bifurcation spur is pretty nearly bisected by the upper limit of the thorax, the dome of the pleura (see Fig. 50), so that its true length can be deduced from its upper half. However, the measurement of this upper half and its perpendicular relation to the thorax is rather unreliable in practice. The topographical utilization of the incisura sterni, which, according to skiagrams, nearly corresponds to the lower third of the trachea (see Fig. 50), adds still greater difficulties. The oblique angle of the upper aperture of the thorax, a portion which has been acquired very late phylogenetically, with the assumption of the upright posture, is subject to such extensive variations that the sternal notch, which is normally situated on the level of the first or second thoracic vertebræ, may vary between the seventh cervical and the fourth thoracic vertebræ.

This is also the main reason of the apparently very variable length of the neck, and the consequent variable position of the upper end of the trachea—*i.e.*, the cricoid cartilage. This point is also very variable in its relation to the cervical vertebral column. While normally it occurs at the level of the seventh or eighth cervical vertebra, it may (see Mehnert) in children occur as high as the fourth cervical vertebra, and in old people even at the first thoracic vertebra.

These topographical considerations lead to the third important

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* "Uber topogr. Altersveränderungen des Atmungsapparates." Jena, 1901 (zit. n. Wild).

PLATE XII.

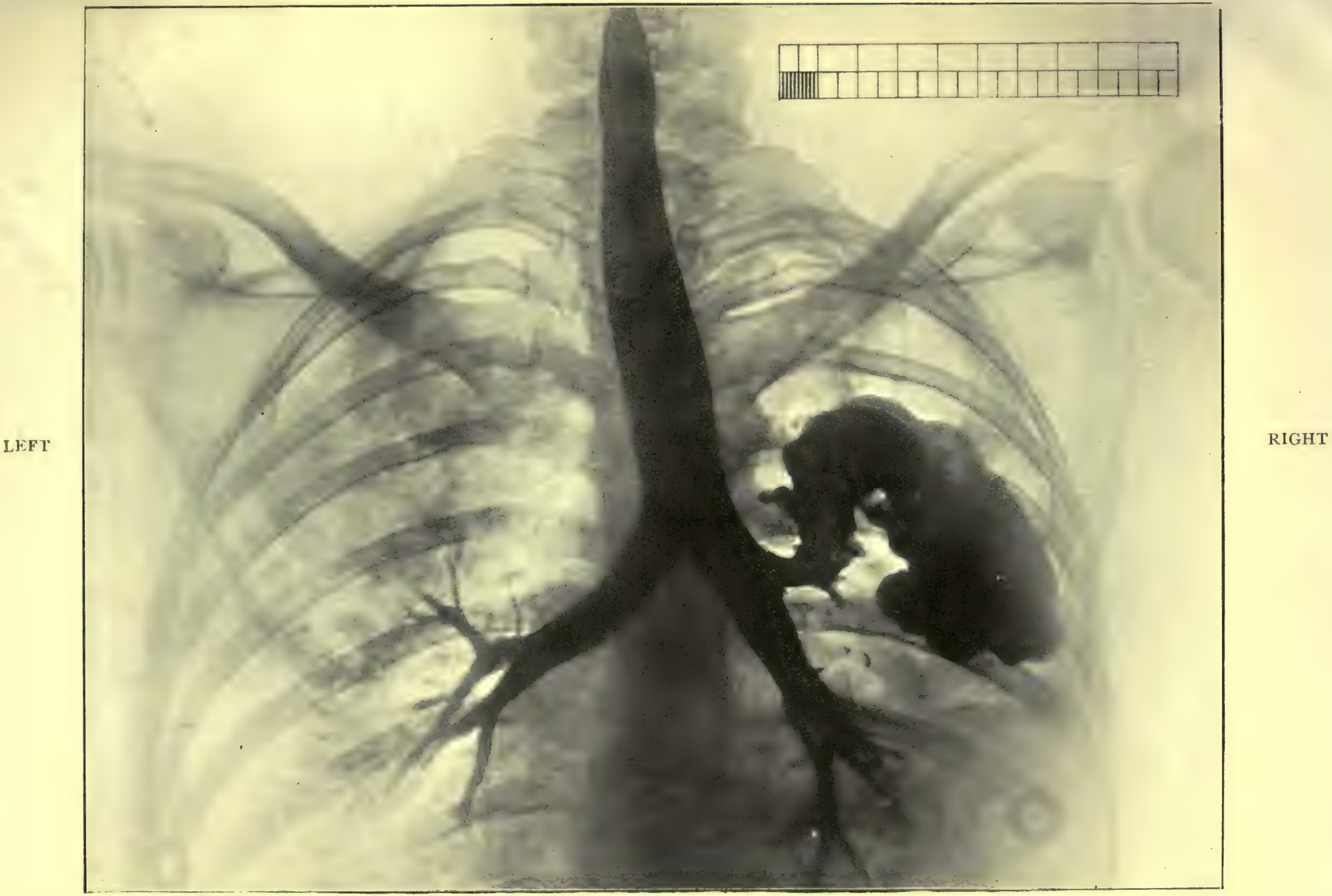

FIG. 54.—ORTHOGRAPHIC REPRESENTATION: CAVITY IN RIGHT UPPER LOBE; SPINDLE-SHAPED DILATATION OF THE TRACHEA (THIRTY-YEAR-OLD WOMAN).

To face page 134.

property of the tracheo-bronchial tree, which has not yet been discussed—*i.e.*, the

Relative Proportions.

Exact numerical data are again difficult to obtain here, for, in the case of absolute measures, not only individual variations but also the relation to the size of the body and the age of the subject has to be dealt with.

Anatomical tables,* when they refer exclusively to age, are of limited utility, and so I have made an attempt to obtain practically useful relative values by taking a great number of systematic measurements. With this object—as the first point to ascertain was the distance between the upper teeth and the bifurcation—I caused the distance between the two articulations, the prominentia laryngis and the upper teeth, to be measured with calliper compasses in subjects of very various ages or rather sizes, while the head was bent back, and these measurements were brought into relation to the length of the body. I found that it was not possible by this means to deduce anything like a constant relation, and I entirely gave up the measurements when I found how little topographical value attached to the second costo-sternal articulation. A remarkable discovery was that the proportion between the upper teeth and the prominentia laryngis, and the distance of this point from the second costo-sternal articulation, which in adults is about 1·1, is modified in favour of the former interval in proportion as children are smaller. This is, no doubt, owing to the relatively advanced development of the child's facial skeleton.

The absence of exact measurements of the tracheo-bronchial tree is, fortunately, no great disadvantage, as in using extensible tubes approximate estimates are sufficient. In order to afford some guidance, I add a small table, which I have composed from measurements of skiagrams and from autoscopic data.

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* A synopsis is given by Gottstein in *Mitteilungen a. d. Grenzgebieten der Mediz. und Chirurgie*, 3 Supplementband, 1907.

RELATIVE LENGTHS OF THE BRONCHIAL TREE.

Lengths.	Man.	Woman.	Child.	Infant.
	Cm.	Cm.	Cm.	Cm.
Trachea	12	10	7	4
Right main bronchus ...	2·5	2	1	0·5
Left main bronchus	5	4·5	3	1·5
Right trunk bronchus ...	3·5	3	2	1
Left trunk bronchus	2	1·5	1	0·5
If the rectilineal distance from teeth to trachea is added ...	12	13	10	12
There is thus as total distance between upper teeth and bifurcation	**26**	**23**	**17**	**12**
And as total distance between upper teeth and lower lobe branches—				
Right	**32**	**28**	**20**	**13·5**
Left	**33**	**29**	**21**	**14**

In this table the term "child" implies the age of about ten years. The numbers in this column have only a limited application, because there is, of course, a considerable interval between "infant" and "woman." The autoscopic numbers for infant and child are doubtful because they depend solely on estimates. It is found that, owing to the relative size of the head, a very large part of the total distance falls within the autoscopic region.

No smaller fractions than half a centimetre are given, as more precise data would serve no purpose owing to the great individual variations. In practice (which will be discussed in Chapter V) these variations must be taken into account by adding about 10 per cent. to the mean values given when choosing instruments. In the selection of extensible tubes the main point will be the width of tube which is practicable. A few remarks on relative calibre must therefore be added. As has already been seen from the skiagrams, the diameters of the tracheo-bronchial tree vary considerably according to level, as the bronchi are not strictly cylindrical. Moreover, the cross-section varies more or less from the circular, whereas in endoscopy only the latter can be taken into account by the tube. Therefore in the following table (Röntgen measurements) only practical mean values are given:

RELATIVE CALIBRE OF THE BRONCHIAL TREE.

Diameters.	Man.	Woman.	Child.	Infant.
	Mm.	Mm.	Mm.	Mm.
Trachea	15-22	13-18	8-11	6-7
Right main bronchus ...	12-16	10-15	7-9	5-6
Right trunk bronchus ...	9-12	8-11	5-7	4-5
Left main bronchus	10-14	9-13	6-8	4-5
Available width of glottis ...	12-15	10-13	8-10	5-6·5

These numbers in themselves afford considerable scope, but in practice it must be remembered that all parts of the tracheobronchial tree are capable of a not inconsiderable power of stretching. I have therefore given rather high values for the available width of the glottis (the width which the tube can traverse) in the case of a child or infant, as compared with the figures of the bronchial tree, because a child's larynx is more expansible. In practising endoscopy, unless there is a special reason for the contrary, it will be advisable to adhere rather to the lower figures as regards the width of tube, as by this investigation is made less troublesome and the mobility of the tube greater.

It may be taken as a rule that a tube of a width that can pass the larynx without difficulty can also enter the two main bronchi. Jackson's statement, that a tube with a diameter of more than 10 millimetres cannot be passed through the larynx "without risk of injury," does not at all apply to the sloping tube spatula of my extensible bronchoscope. I have occasionally examined men with tubes of 14 to 15 millimetres—*i.e.*, with twice the cross-section of Jackson's.

It has already been stated that the diameters of my four bronchoscopic tubes (or their tube spatulæ)—viz., 12, 10, 8·5 and 7 millimetres—only correspond approximately to the groups man, woman, child, infant. There is much scope, particularly between the widths of 7 and 8·5, so that occasionally it is desirable to have an additional tube of 7·75 millimetres for children between one and four years of age. I should like particularly to remark that the 7-millimetre tube cannot be used until a child is from four to five months old. Consequently, in the case of very young infants tracheotomy has to be resorted to, because no reliance can be placed on the employment of tubes narrower than 7 millimetres.

II. PHYSIOLOGICAL.

The main interest for endoscopy, as regards the functional properties of the tracheo-bronchial tree, lies in the physiological movements of the region which is endoscopically visible, and physiology has not hitherto concerned itself much with this matter. For what follows I have been, therefore, obliged to rely chiefly on my own investigations.

Apart from occasional subsidiary movements, two main forms of movement normally occur—respiratory and pulsatory. The former may be subdivided into changes of position either of the entire tracheo-bronchial tree or of certain portions, and changes of lumen. They will be discussed in this order.

Movements due to Respiration.

In order to understand the general changes of position which respiration produces in the large main tracheal branches, their position with regard to the mass of lung tissue must be remembered. The orthostereogram (Fig. 52) plainly shows that by far the greater mass of alveolar tissue is arranged about the large bronchi caudally, laterally, and ventrally, and these bronchi accordingly give out mainly lateral branches, a few ventral and still fewer dorsal branches. This arrangement entirely coincides with the directions of movement, which are communicated to the lungs by the expansion of the thorax in respiration. Caudally (diaphragm) the expansion is greatest; after it comes lateral expansion (movement of the ribs), then ventral, and in the last place dorsal and medial expansion (mediastinum).

This position of the large bronchi with regard to the alveolar tissue, and the direction of movement of the respiratory expansions of the thorax must be considered in so far as is practical, because in virtue of it the great tracheal branches are able to maintain a surprising degree of immobility even during violent respiration. This great relative immobility, and not the slight displacements which actually occur, is worthy of remark. If the lung tissue were arranged concentrically round the large branches, the latter would be obliged to execute very considerable movements with every breath, since medially and dorsally no respiratory expansion of the thorax takes place.

This consideration shows that the great tracheal branches are subject to but slight respiratory movements, a view which is in contradiction with many bronchoscopic data. Such data, however, frequently leave out of account an error which necessarily involves other errors. In every case of bronchoscopy, if the tube is carried beyond the bifurcation, the forced straightening occasions very considerable changes of position of the bronchi under review, in consequence of which possibilities of expansion, and consequently the respiratory movements of the bronchi, are influenced in an uncontrollable manner.

Only an observation of the bifurcation from the trachea, which is not displaced laterally with the tube high, is permissible, but this shows so little that no light is thrown even on the respiratory behaviour of the main bronchi. If, on the other hand, the tube is passed into them, they become displaced medially (see Figs. 65 and 66), the medial expansibility is consequently reduced, and the result is that both these and the lower branches appear to move laterally during inspiration.

In view of the current erroneous opinions in the matter, I have studied the matter by the orthodiagraphic method in the following manner: Two extremely thin-walled india-rubber tubes, each 12 centimetres in length and 4 millimetres in width, were closed below with pieces of lead, filled with mercury, and joined at an acute angle by means of a **Y**-shaped piece of lead. This extremely flexible rider was placed, by means of upper bronchoscopy, on the bifurcation of a man thirty years old, with sound lungs, so that the tubes on each side passed through the main bronchus, stem bronchus, and lower lobe branch, reaching nearly to the diaphragm. The patient was made to breathe strongly while sitting, and several inspiratory and expiratory orthodiagrams were taken by a skilled observer (Weingärtner), the exactly concordant results of which are shown in Fig. 56.

The following particulars must be noted with regard to procedure. The orthodiagram was inscribed (with the large Grödel III. apparatus) simultaneously on the thorax and on a surface not visible to the investigator. This check was required since the respiratory bronchial displacement appears considerably enlarged on the thorax itself, as this rises during inspiration, while the bronchial tree falls. This seems to have been the principal source of error hitherto in observing the respiratory movements of foreign bodies on the Röntgen screen. In estimating the amount of displacement, the ribs are taken involuntarily as a point of comparison, and the movement of the ribs, which is contrary to that of the bronchial tree, is mistakenly added to the movement of the foreign body. (It is easy to see that foreign bodies in bronchi appear indistinct in skiagrams, unless taken while breathing is arrested, owing to the smallness of the objects in question.) I have therefore checked the thoracic picture with the help of the control drawing, on which only the absolute displacements of elevation were registered, and then photographed the patient. The alteration in the position of the diaphragm rendered visible by the double outline is likewise registered orthodiagraphically (Fig. 56).

The figure shows that, as a matter of fact, the large bronchi suffer but slight respiratory displacements. With the maximum inspiration they fall about 1 centimetre downwards with but little change of angle.

This agrees very well with the following result of an experiment. If a light forked piece of aluminium is placed on the bifurcation as presented by a tracheoscopic tube in the high position, the piece of aluminium will suffer respiratory displacement against the upper edge of the tube. The degree of this may be roughly estimated by a scale, although an exact registration is prevented by the pulsatory movements of the bifurcation. The values observed in my experiments were certainly always below 1 centimetre.

With regard to the movements of the bronchial branches in a dorso-ventral direction nothing precise is known. A slight inspiratory ventral movement probably takes place, which may be observed tracheoscopically at the bifurcation; this is explained by the absence of an inspiratory expansion of the thorax backwards. I have not measured the amount of displacement, but estimate it at ·75 centimetre at most.

The foregoing considerations and experiments, as I again repeat, refer only to the great traversing tracheal branches—viz., the main bronchi, stem bronchi, and their more or less rectilineal continuation in the lower lobes. Only about this line is the alveolar lung tissue arranged excentrically in the sense that the distribution of mass in different directions harmonizes with the respective respiratory expansions of the thorax. This "functional concentration," as it might be called, is obtained by the arrangement and development of the large side-bronchi. Within these side-bronchi, as appears plainly on stereograms, the minor branches are rather "anatomically centred"—*i.e.*, the respiratory tissue is arranged more concentrically about the various diverging lines. It may therefore be assumed that rather considerable movements occur here, but experiments have not been carried out to ascertain this, and would meet with many difficulties. Bronchoscopic observations involve errors for the above-named reasons. A notion of these movements may be gained by placing both hands side by side with the index-fingers touching, and then spreading them out. This example, however, errs in that the fingers are in the same plane, and arise on the same level at too acute an angle.

This description renders it intelligible that, in the event of pathological disturbances of the functional activity of the respiratory tissue, deviations from the normal bronchial movements must occur, or that extensive respiratory movements may take place where the parts would normally be at rest. A detailed consideration of possible consequences, the bronchoscopic checking of which would encounter the above-mentioned difficulties, is beyond the scope of this book. The movements of the bifurcation which occur as a result of such conditions cannot, likewise, be discussed.

It is noteworthy that the physiological respiratory movement of the bifurcation is normally slight, and is transmitted visibly to the larynx as a movement of the larynx in the opposite direction. I have not been able to observe any (or only very slight) corresponding movements on the orthodiagraphic screen occasioned by swallowing movements or bending the head, when a rider on the bifurcation is used as an indicator. This is obviously due to the great elastic expansibility of the trachea in a longitudinal direction, for the fact that it can be displaced within the extremely loose surrounding tissue (a fact taken advantage of in operations) would make such a transference very easy. Sudden impulses, moreover, as the Olliver-Carderelli symptom shows, appear to be propagated in a wave-like manner.

When the neck is moved, the upper end of the trachea is displaced by 4 centimetres, and according to other statements (see Wild, *loc. cit.*) it may even amount to some 65 millimetres when the head is extended as far as possible, so that the trachea must in such cases be subject to an elastic longitudinal extension of from 20 to 40 per cent.

Summary.—I sum up the view of the respiratory movements of the bronchi chiefly as follows:

1. The great traversing tracheal branches (main bronchus, stem bronchus, lower lobe branch) fall about 1 centimetre with a maximum inspiration, without any important alteration of their angular relations. When the bronchoscopic tube is introduced, the medial displacement produces a greater artificial lateral movement.

2. Whereas the relative immobility of the main bronchi is to be explained by their "functional centring," the more "anatomical centring" of the lateral bronchi must act like an inspiratory spreading movement, while the angles at the divisions straighten

and enlarge. During endoscopy these movements may appear to be either increased or diminished, according to the direction in which the tube produces displacement at the moment.

Respiratory Changes of Lumen.

Many contradictory views continue to be held with regard to this form of movement and the causes underlying it. It should therefore be advisable to consider the object and importance of the factors at work from known facts, and afterwards to subject theoretical inferences to the practical test of observation and experiment.

For this purpose it is appropriate, without prejudice to the main facts, to represent the tracheobronchial tree and its terminations in the alveoli in the simplified form of a forked tube ending in two small bags (Fig. 57). The degrees of resistance of the walls are represented by three degrees of thickness of line. T represents the rigid wall of the thorax, the contents of which may be increased or decreased by the piston S representing the diaphragm. In order to make it more intelligible, an interval has been shown between the lung tissue and thoracic wall, but in reality this must be thought of as incompressible as if it were filled with a liquid. The fact, however, that a considerable part of the trachea, together with the larynx, is situated outside the thoracic cavity is of essential importance.

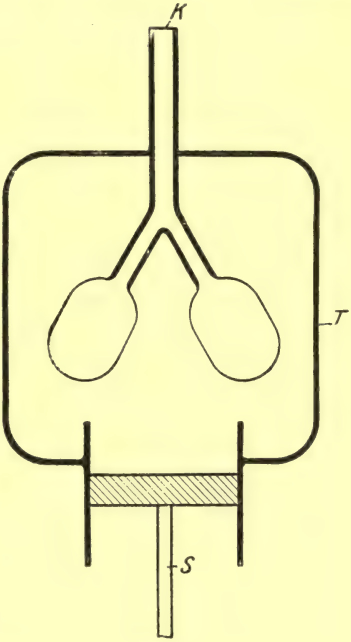

FIG. 57.

If the larynx K is closed, and an elastic pressure exerted by the piston S, the compressible contents of the thorax—*i.e.*, the air contained in the alveoli, bronchi, and trachea—is compressed, so that its volume, with a maximum expiratory movement (1 to 1·5 atm.), falls to half its former amount, or less. As the same amount of pressure occurs throughout the tracheal tree, the diminution of the wall corresponding to the decrease of volume will be distributed over the various sections inversely to their capacity of resistance. It is almost exclusively the alveoli, which are extremely yielding in comparison with the tracheal branches, that are compressed, until a new condition of equilibrium between pleural and pulmonary pressure is reached (= internal pressure of the tracheal tree + alveoli).

A sudden disturbance of the equilibrium thus attained may now occur by the sudden opening of the larynx. At this moment the pulmonary pressure is relieved in accordance with the law of diffusion of compressed gases. At the level of the larynx, which may be considered as the upper extremity of the air-passages, it momentarily falls to zero, while towards the alveoli it increases in such a way that its amount for its transverse section is proportional to the sum of all those frictional resistances which the outflowing air has to overcome in its passage through the larynx. The immediate consequence of this is that the equilibrium between pleural and pulmonary pressure still obtaining in the alveoli is disturbed unfavourably for the tracheo-bronchial tree the farther the movement is from the alveoli towards the larynx. Therefore, at the moment when the larynx opens, an external pressure increasing towards the larynx must operate upon the tracheo-bronchial tree, the effect of which in reducing the lumen depends at each point on the local relation between the difference of pressure and the resistance of the walls. The decisive circumstance affecting actual conditions is that the stiffening of the bronchial walls from the alveoli to the larynx evidently progresses more rapidly than does difference of pressure.

It is scarcely necessary to point out that these observations apply also for the contrary case—inspiration with closed and suddenly opened larynx—the directions of pressure and movement being reversed.

I have selected an extreme case of the respiratory mechanism because in it the processes are rendered most evident. In principle the mechanical effects of every ordinary inspiration and expiration are the same when pressure is increased and the larynx suddenly opened, as in the case of a cough. For during every expiration the proposition above deduced holds valid—namely, that the internal alveolar pressure approaches most nearly to the pleural pressure, and least to the internal tracheal pressure, and that the difference of pressure for every cross-section is equal to the sum of atmospheric resistances occurring in the direction of the larynx.

The practical consequences of this law will be seen later on, but I must here add a limitation, which I have ignored for the sake of clearness, namely that a considerable portion of the trachea actually lies outside the thorax (see Fig. 50), so that quite different mechanical conditions apply to it. For as in this section it is, in the main, only atmospheric pressure that operates from without, at every variation of endotracheal pressure it simply suffers a degree of compression or dilatation proportional to the amount of such variation. An example of this can readily be pointed out. If a forced expiration with closed glottis is made, the larynx rises considerably while the extrathoracic part of the trachea expands; and when the glottis is suddenly opened, as in coughing, it immediately returns to its former position.

A second limitation of the laws affecting the passive respiratory changes of lumen may be seen in the active part taken by the bronchial muscles—at least in those bronchi which have no cartilage, and whose lumen does not exceed 1 millimetre. As a matter of fact, in curarized animals with artificial respiration, the measured frictional resistance of the atmosphere increases when bronchial irritants (gases or steam) are present, which can only be explained as a result of the contraction of the circular muscles of the smaller bronchi and bronchioles.*

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* Further particulars on this subject are given by Lazarus in *Archiv f. Anat. u. Physiol.*, 1891; and Einthoven, *Pfluger's Archiv*, Bd. li., 1892.

In my attempt to check, by experiment, the theoretical views which are described above, I proceeded as follows:

On short tracheoscopic tubes of various diameters a cap was fitted, and made air-tight by means of a mirror placed obliquely. This cap was provided laterally with a tube attachment which could be gradually narrowed or connected with a manometer by means of a flexible tube. In this manner I manufactured, as it were, a transparent larynx at the end of the tracheal tube prolonged by the instrument, by means of which, even when the glottis was closed, the effect of various pressures on the condition of the lumen could be observed.

To observe the trachea I introduced a wide tube of this kind a short way past the larynx of suitable subjects, just far enough to make it completely or nearly air-tight. The air can never be entirely excluded during expiration, because when pressure is much increased air can always escape. I selected a tracheotomized subject in whom the opening of the trachea could be effectively closed. In this way experiments may be conducted with ease and accuracy. To examine the bronchi, a longer tube was pushed down to the bifurcation, so that it was possible more or less to watch the right main bronchus while effecting suitable displacement. A shutting off of the main bronchus itself, which of course can easily be effected, does not answer the conditions of the experiment, because when the other lung is left free a full expiratory pressure can never be obtained in the region which has been shut off.

In order to avoid clouding, the mirror was coated with diaphanine, but when observation was continued for a long period it was also found necessary to close the lateral opening at every expiration, so that the current of air might not directly meet the mirror but escape between the tube and the larynx.

With this arrangement I was able to verify the accuracy of my first theoretical conclusion that the lumen of the trachea and the large bronchi does not noticeably alter even when the positive and negative variations of pleural pressure were as great as possible, so long as the glottis is closed. The experiments were so conducted that the subjects first breathed without the cap, or with the lateral opening fully open, and afterwards, when the air was excluded, they had to execute several (abortive) respiratory movements as forcibly as possible. Variations of pressure of more than one atmosphere occur, and in these circumstances considerable alterations in the lumen should take place even in those bronchi which are stiffened on three sides by a cartilagious ring. It is therefore extremely probable that, under the given conditions, respiratory variations of lumen may be excluded even in the smaller bronchi which are not directly visible.

It was likewise possible conclusively to prove the correctness of the second theoretical inference—namely that, when the closure of the glottis is suddenly removed, a considerable narrowing of the trachea and of the large bronchi must occur. The experiment was made as follows:

When the expiratory pressure was at its maximum, I suddenly let the closing cap spring off, or opened the lateral aperture. A momentary diminution of the bronchial orifices and a collapse of the lower section of the trachea could then be observed, and this was caused chiefly by a forward bulge of the posterior membranous wall. It is very difficult to follow closely the changes which present themselves from moment to moment, because when the cap is taken off the expiratory blast strikes the cornea in a manner which is unbearable, and if the lateral aperture is relieved the glass is rapidly clouded.

When the lateral aperture was gradually closed—a condition which realizes all degrees of stenosis breathing—no visible change of lumen occurred even during violent breathing. This agrees with the theoretical premises, and is explained by the absence of those conditions which cause sudden differences between pleural and pulmonary pressure.

The mechanical conditions of the second experiment—the sudden opening of the glottis during strong expiratory pressure—may also be imitated by suddenly increasing pleural pressure while the glottis is open. This process only occurs spontaneously if the vocal cords are paralyzed and the subject attempts to cough.

Through the introduced tube every act of coughing can be observed. In this case, also, an absolutely momentary diminution of the tracheal and bronchial lumen is always seen, mainly as a consequence of the forward bulging of the posterior wall.* I imagine that the change of lumen produced in this way is never as great as that caused by the sudden relaxation of the glottis, for in these processes everything depends upon the rapidity or suddenness of changes of pressure. Owing to the considerable amount of air contained in the lungs, an increase of pleural pressure can never be as sudden as the decline produced by a sudden opening of the glottis.

The fact that the coughing up of secretion is rendered more difficult when the vocal cords are paralyzed may have some relation to the above, since its passage depends not only on the rapidity of the expiratory current of air due to the difference of pressure, but because, the difference of pressure being equal, the rapidity of the air current is inversely proportional to the square of the diameter of the tube—*i.e.*, it increases rapidly as the lumen is diminished during expiration.

The significance of this fact is at once apparent if it is considered how difficult it would be for bronchial or tracheal secretion adhering to the walls to be removed by the expiratory current if the tubes were entirely rigid. The expiratory diminution of lumen not only has the effect of increasing the rapidity of the current of air in the circumscribed region—as much as ten to twenty fold—but during the transient complete collapse it may, through violent coughing efforts, convert the frictional action of the air current upon this secretion into a directly propellent effect. This mechanism is, of course, of greatest importance for the wide trachea, and I believe I am not wrong in assuming that the physiological significance of the paries membranacea must be mainly sought in the possibility it affords of a passive expiratory reduction of lumen.

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* It is obvious, of course, that with reference to these endoscopic observations of the normal breathing processes, such as may be observed any day, I do not make any claim to priority. To Pieniacek belongs the merit of having furnished the first exact data. Later on F. Ingals and H. v. Schrötter have given their views, but without establishing a theory.

Active contractions of the unstriped muscle of the trachea and large bronchi are not known to physiology.* If Landois (*Manual of Physiology*, 10th edit., 1900) considers the purpose of the unstriped muscle fibres to be to afford assistance "to increased pressure within the air-passages (as in all cases of forced expiration—*e.g.*, speaking, singing, blowing, straining)," this view is due to the prevalent error of imagining that the expiratory pressure operates by causing expansion of the air-passages. That can never be the case, since the pulmonary (internal) pressure is always less than the pleural (external) pressure.

The fact has already been emphasized that ordinary respiration presents, in principle, the same character as the sudden relaxation of the glottis, or the act of coughing when a tube is introduced. In ordinary respiration, however, owing to the gradual compensation, the difference of pressure never reaches such a degree as to cause great changes of lumen in those bronchi which are endoscopically visible. In fact, with adults no respiratory movements whatever are visible in the trachea and the large bronchi, and with ordinary breathing I could not ascertain their presence even with delicate measuring instruments. If some authors assert that such changes of lumen do occur, they must have had in view either young persons or cases of abnormally strong breathing. It need scarcely be said that there are many stages between quiet breathing and forced coughing (with a tube introduced).

Young persons or children show respiratory changes of lumen very much more strongly than adults. This is due to the fact that in their case the consolidation of the trachea and its branches is still so imperfect that even the smaller differences of pressure usual with children may occasion very great alterations of the lumen. In little children it is seen not infrequently that the clear spaces in the trachea and main bronchi completely disappear with forced expiration. I have further observed that these patients continue to cough loudly after the tube has long passed the larynx and even the bifurcation. The noise of coughing arises in this case from the momentary expiratory occlusion of the air-passages. It has quite the raw character of the so-called "croupy cough," in which condition there is also an expiratory occlusion below the vocal cords.

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* The statement of Nicaise ("Physiologie de la Trachée et des Bronches," *Rev. de Méd.*, November, 1889), that the tracheal muscles are contracted by deep inspiration and relax in strong expiration, has not so far been confirmed. Compare also Lejars, *loc. cit.*, p. 211.

The great alterations of the lumen in children are of great importance for endoscopic investigation. Indeed, with children it is often only possible to obtain a view during inspiration, and a diagnosis must often be made, or an operation performed during the brief moments of accelerated breathing. This difficulty will be referred to later on.

Summary.—The results of my investigations concerning respiratory variations of lumen may be briefly stated as follows:

1. If, while the expiratory pressure is great, the glottis is suddenly released, or while the glottis is open a sudden expiratory pressure is produced (cough), a great difference between pleural and pulmonary atmospheric pressure is produced, and this pressure decreases from the larynx downwards to the alveoli. The consequence of this is a momentary reduction of the lumina of the trachea and visible bronchi, the amount of which is determined by the relation between the differential pressure and the yielding of the walls.

2. Calm breathing proceeds along the same lines as the extreme cases just mentioned, but in adults, owing to the slight degree of difference in pressure, there is no respiratory modification of lumen in the trachea and visible bronchi. It must also be expressly stated that, even when breathing is rendered difficult through stenosis of the larynx or trachea, a condition which would imply greater variations of lumen is not produced.

3. In children, owing to the pliancy of the walls, respiratory changes of lumen are much more marked than in adults, so that in the case of strong expiratory efforts a complete closure of the trachea and main bronchi takes place, and is accompanied by

a cough-like noise. In the case of small children, even when breathing calmly, considerable respiratory variations of lumen may not infrequently be met with.

In conclusion, a few words must be said on the extrathoracic portion of the trachea, which, as has been seen above, is subject to very special conditions. In it the compensations from pleural variations of pressure do not exist, and so every endotracheal change of pressure must operate unchecked either as a widening or narrowing, a shortening or lengthening (respiratory up-and-down movement of the larynx in the case of laryngeal stenosis) of it.

In ordinary breathing, changes of pressure in the upper part of the larynx are very slight. They are not even able to produce any noticeable variations of lumen in the posterior membranous wall, or in any portion of the wall where the cartilage has been destroyed. The case is different when breathing is forced, for then the pliable portions frequently fall considerably during inspiration, so that when constriction already exists inspiratory stenoses supervene. The mechanism of these respiratory alterations of the lumen, as there explained, is also a help to the understanding of the behaviour of extra- and intra-thoracic stenosis. The former (unless special ventilation mechanisms interfere) must always impede inspiration, and the latter expiration.

The pliability of the extrathoracic part of the trachea can be very well demonstrated with the aid of the closed tube already described. For if the respiration is obstructed by gradually narrowing the lateral tube, relaxed portions of the wall are soon revealed by inspiratory bulging forward. In cases where the removal of a tracheotomy-tube presents difficulties, a decision may be arrived at whether collapse of the wall plays an important part, and in cases of struma compression an opinion may be formed whether any considerable prolapse of the wall has occurred in the region of the stenosis. Unfortunately, the applicability of this method is restricted to subjects who are particularly amenable to autoscopy.

Pulsatory Movements.

The close proximity of the heart and of the great arteries explains how their pulsatory movements are transmitted to the tracheo-bronchial tree. The phenomena accompanying these have no particular significance for this method, and they may therefore be passed over briefly.

Regular pulsatory movements of the bifurcation, occurring simultaneously with the systole of the heart, may be seen with the tube in the high position. In addition to these pulsatory movements, which chiefly concern the neighbourhood of the bifurcation, regular systolic bulgings in the lowest part of the left tracheal wall may be observed.

There can be no doubt that these are merely passive movements of the air-passages in sympathy with the pulsations of the large vessels, including, perhaps, the heart. The relations of the vessels are rather complicated, for the right branch of the pulmonary artery, which lies behind the aorta, passes in front of the right main bronchus and below the right upper lobe branch; whereas the left branch, after crossing the left main bronchus at an acute angle, as it passes under the arch of the aorta, crosses above the upper lobe branch. The complexity of these local relations, together with the time variations of the various pulses, makes it possible to understand that the movement of the bifurcation, resulting from variable factors in space and time, are of an inconstant and irregular nature. Occasionally there is almost complete absence of movement owing to accidental interference, while at other times lateral movements up to 3 to 4 millimetres may occur, and these are complicated with more or less pronounced movements in a dorso-ventral direction. Even the direction of lateral pulsation is not constant, and so the entire phenomenon does not furnish a basis on which to build conclusions.

A much more constant and unequivocal character is possessed by the systolic bulging of the left tracheal wall produced by the neighbouring aorta, although even here considerable quantitative differences normally occur. This phenomenon is occasionally of diagnostic importance, because aneurisms of the aorta may, according to their position and size, produce quantitatively and qualitatively abnormal pulsations, of which it is needless to give a description here.

The larger bronchi are made to pulsate by the branches of the pulmonary arteries which accompany them, but the direction of pulsation is naturally very variable. Occasionally these movements are so marked that the bronchial lumen may vanish rythmically from the field of vision. This naturally renders observations and operative interferences much more difficult.

All the pulsations decrease in intensity during inspiration, owing to the inspiratory fall of blood-pressure. They increase during expiration, and the increase is maintained over the pause between expiration and inspiration. If the constriction of the lumen above described occurs during forced expiration, the current of air may occasionally acquire an audible and jerky character synchronizing with the pulse. This phenomenon is in no way connected with the cardio-pneumatic movement of air, which of course continues even during the intervals of breathing. I have separated the two by the aid of a very sensitive multiplying aneroid-indicator.

The beginner will be struck by the extraordinary force with which pulsatory movements are transmitted to the tube. This phenomenon is most marked when the main left bronchus is entered by lower bronchoscopy, and the tube lies under the arch of the aorta. The upper end of the tube makes visible excursions, and if the tube is held fast these are communicated with uncanny force to the arm of the surgeon.

Finally I must mention one other lumen movement of the trachea, which may be termed "deglutatory compression," to distinguish it from the usual rising and falling movement due to deglutition. Owing to the immediate contact of the paries membranacea of the trachea with the œsophagus, a swallowed morsel of sufficient size must produce a bulging of the posterior tracheal wall, so that with every act of swallowing a sort of peristaltic narrowing runs along it. It is only in children, in whom the trachea is very compressible, that any considerable narrowing is thus produced. When engaged in œsophagoscopy, it is important to bear in mind that the trachea may be compressed from the œsophagus, because a clumsy manipulation of the tube may produce some obstruction to respiration.

In the next chapter mention will be made of the degree of mobility of the tracheo-bronchial tree that may be brought about by the tube when introduced, and the endoscopic pictures will also be referred to.

CHAPTER V

DIRECT TRACHEO-BRONCHOSCOPY

THE systematic examination and treatment of the trachea and bronchi by the peroral introduction of straight tubes was initiated by Killian in 1896. After being successfully applied in a case of a foreign body lodged in the bronchi it was recommended in 1897 as a clinical method.

An inspection of the trachea and—as far as this is possible without undue displacement—of the entrances to the main bronchi had been carried out as early as 1875 by Voltolini* through a tracheotomy wound, and after him, especially by Pieniazek and L. von Schrötter, by the aid of specula of the aural type. In cases in which the laryngeal reflex sensibility was low, œsophagoscopists occasionally discovered, after withdrawing the mandrin, that they had got into the trachea, only to retreat hastily as soon as they perceived their mistake. Von Hacker and Rosenheim† were the only observers who ventured to make a diagnostic inspection in this "dangerous region," until, in 1895, Kirstein began to pass the straight tube through the larynx intentionally. But he, too, was probably impressed with the dangerous nature of the experiment, and refrained from pursuing this illuminating path and exploring a pulsating region of such a high degree of reflex sensibility.

This prejudice was refuted by Killian, to whom direct tracheoscopy from above as a method is due. Killian, too, by a systematic advance opened up a new and still more important region for practical purposes—namely, the bronchial tree.

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* *Berliner Klin. Wochenschr.*, 1875.

† Compare Killian, *Verh. d. Ver. südd. Laryngol.*, 1898.

Bronchoscopy presented (at least as regards the air-passages) a new endoscopic problem — namely, the straightening of the tracheal branches which of course follow a distinct angle. Similar displacements had, indeed, previously been made during the endoscopy of the œsophagus and urethra. In the present case, however, the organ under consideration is normally exposed only to delicate contact with a gaseous medium, and by its vigorous reflexes opposes the entrance of solid foreign bodies. It has, moreover, to be examined without its vital function being interrupted.

Killian showed that this was possible, and thereby created a method which has to grapple with problems immediately involving the saving of life, in this respect differing from any other endoscopic problems.

It cannot be appreciated too highly that Killian, starting as he did with imperfect instruments, laboured indefatigably to improve his method, to further its clinical application and to popularize it both by his lectures and writings, thus enabling von Eicken to show in 1904 for the first time the true clinical value of the "direct method of observation," illustrated by abundant material.* It is no longer necessary to preface a statement of the bronchoscopic method by giving an account of its clinical importance, as I did in reference to direct laryngoscopy. Killian's method has become an integral part of laryngological technique, and the "specialistic trick," simplified with the help of new appliances, is beginning to be recognized in surgical and medical clinics.

The reader will be aware that Killian's method is practised ordinarily through the mouth as "direct upper tracheo-bronchoscopy," and through a previous tracheotomy wound as "direct lower tracheo-bronchoscopy." The sequence which the description of it must take follows naturally from this, and, as this presupposes an acquaintance with Chapters I. to V., description is accordingly limited to the purely practical side. In the case of the general manipulation of the bronchoscopic tube, in so far

* *Arch. f. Laryngologie*, Bd. 15, Heft 3.

as it serves as an observation instrument for syringoscopic images, it seems advisable to premise some theoretical observations, as this will simplify the subsequent presentation of the normal course of examination and may also be of value in treating typical problems. Afterwards will follow a section entitled "Preparations," in which some general questions (asepsis, choice of tube, etc.) will be treated.

A. THE SYRINGOSCOPIC IMAGE.

I have already explained that the optical and luminous conditions affecting cystoscopy (the observation of bladder-like cavities of the body) differ so much from those of syringoscopy—the ocular examination of tubular organs—that the instruments required for these two purposes must have an essentially different structure. Similarly, their mechanical and optical manipulation, the "presentation" and "recognition" of the image, will differ. In practice, of course, the two problems cannot always be separated, although mutual interdependence is not nearly so great here as in cystoscopy. Theoretically, on the other hand, it is advisable to treat the two things separately, as in this way the respective principles and the general rules deducible from them can better be expressed.

1. The Presentation of the Image.

Whereas cystoscopy is concerned merely with the observation of a surface situated, more or less, perpendicularly to the line of sight, syringoscopy presents a second and often more important problem—the recognition of the lumen. A general distinction may therefore be made between

LUMEN AND SURFACE IMAGES,

each of which requires a different disposition of the tube.

As in all tubular organs the lumen must be wider than the tube of observation, a varying portion of the organ wall nearest the tube end (*a—b*, Fig. 58) must be left outside of the field of vision, which with central introduction only commences below *b*. From this point downwards, the entire circumference of the walls of the organ, including the lumen, can be observed simultaneously, so that the lumen of the bronchus and of the tube coincide. For the distance between *a* and *b* a view of the walls can only be obtained by examining the whole circumference piecemeal.

It is clear that the length of the interval *a—b* depends on the form of the bronchus tube (relation between length and width) and the difference between its width and that of the organ, but it may be taken as a general rule that lumen images should be examined with the tube high and surface images with the tube low, and that the recognition of each surface image should be preceded by that of the lumen image connected with it.

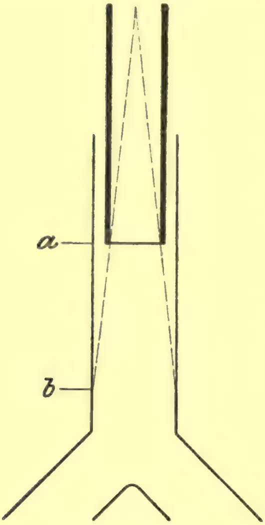

FIG. 58.

Beginners are always very eager to get far down, and if the object to be examined lies below *b* they at once push down to it. This makes difficult the recognition of all those affections which are mainly connected with the lumen image, such as curvatures and displacements of the entire organ, locomotor movements, etc. The examination of such objects with the tube low may yield erroneous results, because such conditions as deviations, deformations, and movements may be altered or suppressed by the introduction of the tube.

When surface images (changes in the mucous membrane, etc.) are to be observed, the tube must be used low and placed obliquely to suit the particular object in view. In this connection it must be remembered that the field of vision diminishes in proportion to the obliqueness of the tube, while the apparent size of the object increases. In one extreme case the whole tracheal wall, 12 centimetres in length, is projected with perspective foreshortening into the end of the tube (tangential position); in the other extreme case it is filled by two to three tracheal rings (perpendicular view). What is characteristic in presenting the image of a wall is the oblique direction of the observation tube with regard to the axis of the organ. In so far as the latter does not itself tend to curve, the oblique direction must be obtained through lateral movements of the tube. The next point to be considered is an expedient which is so important in syringoscopy, namely,

DISPLACEMENT,

for the employment of which some general rules may be formulated.

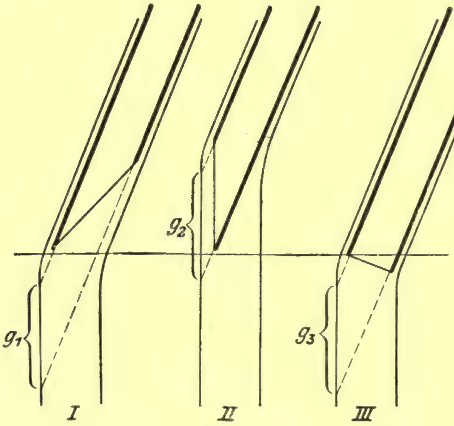

FIG. 59*a*.

In the first place, the use of the tube is different if the end is straight or oblique. Fig. 59*a* shows generally that, in Position II. of the tube, not only is respiration stopped by the tube, but the field of vision is affected by its edge, and in many types of case this position is inadmissible. A comparison with Position I. gives the rule that displacements must always be effected by the longest side of the tube when tube spatulæ are used. Fig. 59*a* shows, moreover, that the extent of the field of vision (g_1, g_2, g_3) is uninfluenced by the form of the end of the tube.

If the tube of the organ is oblique or curved, lateral displacements have an additional object. In these circumstances, for example, merely surface pictures of the lower wall of the organ are obtained, and these afford no information either as to the form of the lumen or its direction. In such conditions a blind advance of the tube is forbidden by the fundamental rule in syringoscopy that the hand should be in every case guided by the eye. Examinations are only rendered safe and free from danger when every spot can be seen before the tube reaches it. In the case of organs which run obliquely this can only be attained by displacement, which in this case has three different purposes — orientation, straightening, and the presentation of lateral branches.

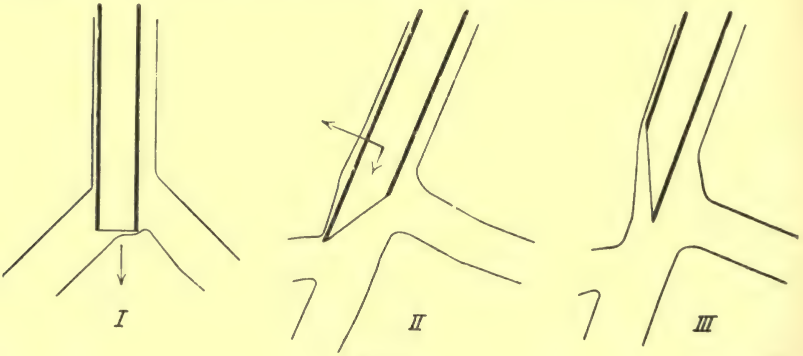

FIG. 59*b*.

Orientation in the bronchial tree requires lumen images of greater extent, as the position of the tube can, as a rule, only be ascertained when several branches, with their relative positions and distances, can be viewed simultaneously. Straightening by advancing the tube is of still greater importance. If, for instance, I were simply to push down the tube in order to obliterate a bronchial angle, like that in Fig. 59*b*, very serious friction with the lower bronchial wall would occur if the angle were acute. Such a procedure is absolutely inadmissible, and, in the case of pathological changes, has led to serious mistakes. The lateral friction of the tube goes far to prevent the operator from estimating correctly the force employed, and a jerky movement is not always avoidable. If, on the other hand, considerable displacement of the bifurcation (Fig. 59*b*) is used to bring the bronchus into the direction of the tubal axis, and the tube is passed down afterwards, all danger is avoided even in pathological circumstances, because it is possible to estimate beforehand the force required for straightening.

Here again the rule must be observed that the displacement has to be effected with the longest side of the oblique spatula-tube (Fig. 59*b*). With the opposite position (Fig. 59*b*) it is scarcely possible—especially with children—to effect straightening without losing the field of vision. In any case a rule should be made not to advance before the lumen has been presented.

The third problem in displacement is the presentation of lateral branches, whether with the intention of passing the tube into them or, in the case of small bronchi, of placing their axes in the direction of vision and procuring a lumen image of them. The most extreme displacement is required when presenting the upper lobe bronchi, as they branch from the lateral wall and follow a horizontal, or even somewhat upward, course. Just as the flexibility of the root of the tongue is a condition for direct laryngoscopy, so the practicability of such bronchoscopic problems makes great demands on the mobility of the trachea and bronchial tree. Abnormal attachments, in the recognition of which the tube frequently yields important results, may make the examination of the main bronchi difficult or impossible. Normally, however, the structure of the trachea, with its fibro-elastic wall traversed by springy cartilaginous rings, placed as it is amid extremely loose tissue or lung parenchyma, admits of quite unusual displacements, which are neither dangerous nor painful for the patient. In Figs. 63 to 66, four

Typical Positions

of the tube are given which are needed in presenting the upper and lower lobe bronchi, and this in such a way that the endoscopic displacement of the bronchial tree can be seen in comparison with its normal length. This is far more instructive than radiography of tubes or sounds which have been introduced.

The pictures were obtained as follows: A particularly rigid bronchoscopic tube 35 centimetres in length (Fig. 61) was connected by a movable hinge with a parallel tube of equal length divided into centimetres, so that the two could open and close like a compass. Before this, a flexible sheath containing mercury had been introduced, and the trachea and main bronchi indicated orthodiagraphically (Fig. 62) on the chest of the patient who was in a sitting position. After the tube had been introduced and the presentation accomplished, the parallel tube was applied to the chest, and its position in relation to the bronchial tree was photographed. (The objective of the camera, placed horizontally, was at the top of the bifurcation, and the photographer had to see that the parallel tubes or their outer ends exactly coincided.)

In this way it was possible to make exact representations of the bronchoscopic displacements. Figs. 63 and 64 show the presentation of the upper lobe bronchi. In this picture, as the surgeon purposely places himself on one side, it can be seen that the tube assumes a very oblique position owing to the displacement of the bifurcation and to the fact that the opposite corner of the mouth is used while the head is inclined sideways. The fulcrum coincides pretty exactly with the larynx, the position of which is relatively fixed by the extension of the head. The greatest displacement occurred in presenting the left upper lobe branch (Fig. 63). The ridge at the bifurcation—and with it the large vessels—here suffer a lateral displacement of quite 5 centimetres (according to the visible division of the parallel tube, which serves as a scale of comparison). The angle formed by the tube and axis of the body or the orthodiagraphed trachea measures about 30°. The tube is somewhat more upright when the right upper lobe bronchus is presented, but here also the bifurcal displacement amounts to 5 centimetres. The bifurcation and the parts near it have therefore altogether to undergo the enormous displacement of 10 centimetres.

Quite a different picture of displacement is afforded by the

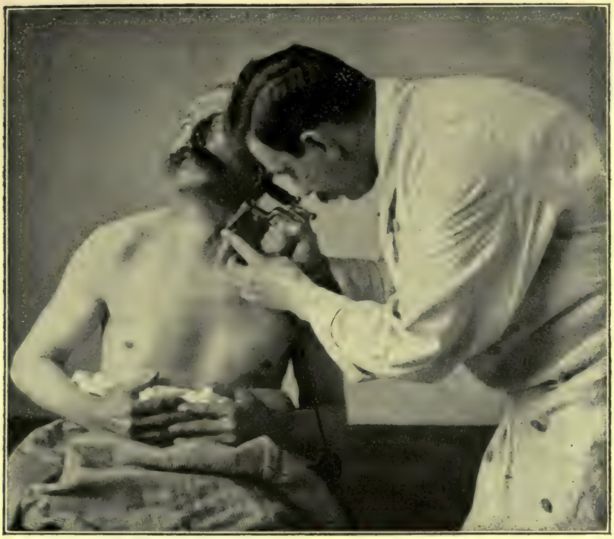

FIG. 60.—LOWER BRONCHOSCOPY (PRESENTATION OF RIGHT UPPER LOBE BRONCHUS).

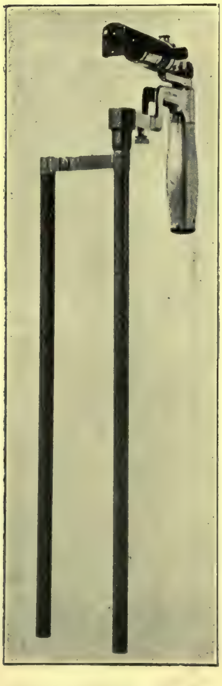

FIG. 61.—PARALLEL BRONCHOSCOPE.

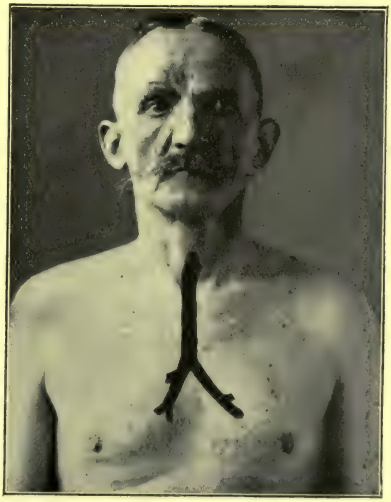

FIG. 62.—ORTHODIAGRAM OF TRACHEO-BRONCHIAL TUBE.

PLATE XV.

TYPICAL POSITIONS OF TUBE.

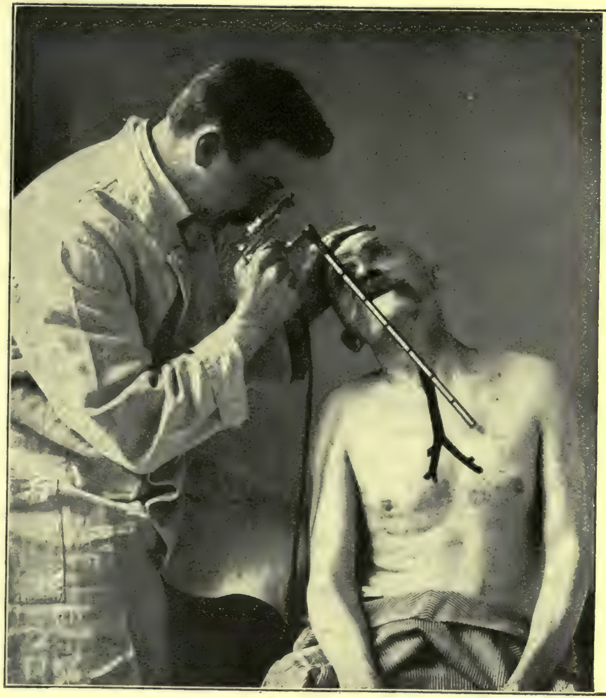

FIG. 63.—PRESENTATION OF THE LEFT UPPER LOBE BRONCHUS.

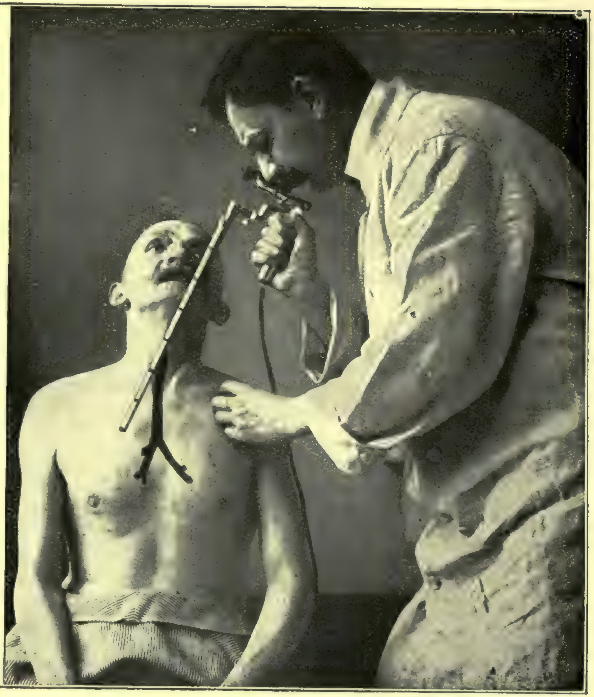

FIG. 64.—PRESENTATION OF THE RIGHT UPPER LOBE BRONCHUS.

To face page 162.

PLATE XVI.

TYPICAL POSITIONS OF TUBE.

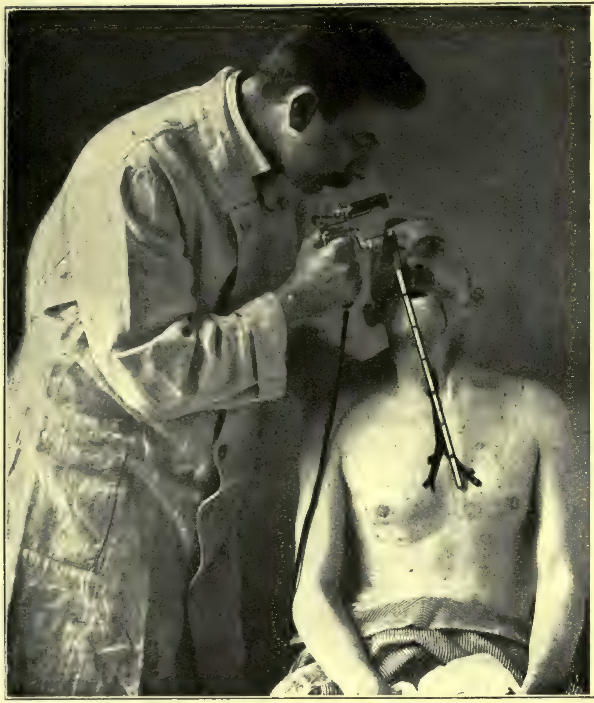

FIG. 65.—PRESENTATION OF THE LEFT LOWER LOBE BRONCHUS.

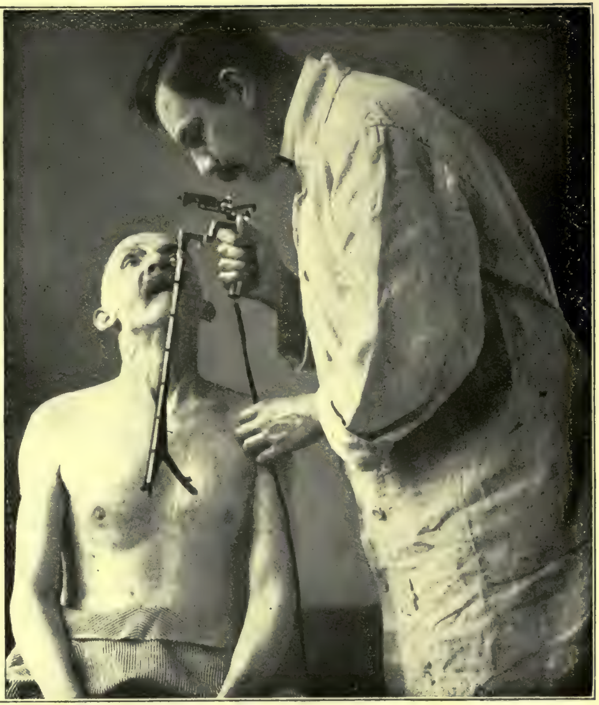

FIG. 66.—PRESENTATION OF THE RIGHT LOWER LOBE BRONCHUS.

To face page 162.

presentation of the lower lobe bronchi. On the right side (Fig. 65), with the perpendicular tube corresponding to the obtuse angle between the trachea and main bronchus, there is only a slight straightening and a bifurcal displacement of about 1·5 centimetres. On the left (Fig. 66) the bifurcation and the main bronchus, which here has a steeper gradient, is displaced by about 1·5 to 2 centimetres by way of straightening. Special lateral displacement of the tube, apart from the oblique direction due to the position of the corner of the mouth, is not required.

It is obvious that in lower bronchoscopy slight displacement procures a sufficient obliquity of the tube, because, owing to the great mobility of the trachea, the fulcrum falls much below the opening in the trachea (compare Fig. 60). Indeed, in the case of a low tracheotomy, it approaches more nearly to the bifurcation. Thus, in Fig. 60, by inclining the tube to an angle of 24° to the axis of the body, it was possible, without difficulty, to present the beginning of the right upper lobe bronchus.

2. Interpretation of the Image.

This does not mean a clinical diagnosis, but the optical interpretation of tube images and their peculiarities which arise from the method of examination. A theoretical treatment of problems raised by perspective vision with one eye is of little use, and I may confine myself to pointing out briefly some of the difficulties which occur most frequently. The distinction already made between surface images and lumen images may here again be kept in mind. In the

INTERPRETATION OF SURFACE IMAGES

there is the general object of observing a surface with one eye, using a simple cylindrical tube. In such an experiment, especially when the parallel-rayed illumination coincides with the direction of sight, it will be found impossible directly to determine the angle of inclination of the surface, because the differences of distance are far too slight for perception with one eye, and visible shadows cannot occur in the direction of observation. The uncertainty in judging of the angle of inclination increases, of course, with the length of the tube. It begins with the structureless surface images of the pharynx, and becomes more apparent in the œsophagus, till, in the stomach, any appreciation of the position of the surface image presented is impossible.

This is of some practical importance, because not only the interpretation of shape and size within the surface image, but also orientation and the direction to be taken, presupposes a knowledge of the angle of inclination. Reliance must, therefore, not infrequently be placed on experiments. Lateral displacements in various directions will either reveal directly the situation of the lumen, or alter the angle of inclination so strikingly as to leave no doubt as to the position of the tube. Two points must be particularly noticed as indicating change of angle—viz., the variation of illumination and of size. The difference in brightness and size between those points which are nearer to the end of the tube and those which are farther from it becomes slighter the nearer the direction of the tube approaches the perpendicular. A more detailed explanation of these conditions is superfluous, because in practice the surgeon is guided rather by instinctive movements of the tube than by theoretical considerations.

In the air-passages there is fortunately a very important guide for judging of the situation of the surface image—viz., the markings of the tracheal rings which keep the operator informed at all times, not only of the angle of the wall, but also of the situation of the lumen. To illustrate this principle, I have represented in Fig. 67 the circular motion of a tube 4 centimetres in width, on whose inner wall the observer looks through another tube at an angle of 90° (*a*), 75° (*b*), and 45° (*c*).

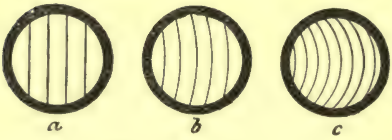

FIG. 67.

In Fig. 67 *b* and *c* show that the form of the ring markings directly reveal the situation of the lumen. The curvature of the rings and the regular decrease of their apparent distances make it possible to judge of the greater or less acuteness of the angle of a bronchial side-branch before the tube is passed into it, and its direction thereby modified. This affords a very important assistance, without which the endoscopy of the complicated bronchial tree would be much less reliable.

THE INTERPRETATION OF LUMEN IMAGES

likewise is greatly assisted by the markings of the tracheal rings, without which there would be great difficulty in deciding between a concentric or unilateral contraction or expansion. If a "lumen presentation" of the part in question can be obtained, the direct impression gained leaves no doubt as to whether it is a case of real contraction of the lumen or an apparent perspective diminution. In the former case the regular intervals between the cartilaginous rings become greater in the contracted area, because the wall is being observed at a more acute angle. Moreover, the different parallactic displacements caused by lateral movements of the tube will indicate whether the organic tube is cylindrical or conical.

This assistance is more or less lacking when the organic tube runs obliquely or in a curve, because its lumen cannot then be overlooked. The distinction between deviations and compressions is in such a case often difficult, because the shape of the wall is changed by the displacement required for presenting the lumen. It is therefore advisable to endeavour first to form an opinion with the tube high, while closely scrutinizing all ring markings. When oblique portions of the wall cross each other, the observer is easily apt to get the impressions of an oval lumen, because rings at the various levels apparently unite to form an ellipse. This is the reason why the first part of the bronchial branches at an oblique angle frequently seem to have an oval section. The surest way of guarding against such errors is to note carefully all differences of level, and if this is done the connection of sections of rings at different levels will be avoided. If the curved shape of small ring segments is correctly judged, it is often possible to decide whether they are parts of a circle of a more or less elongated ellipse, or of a scimitar or heart-shaped section.

In the case of important concentric or excentric stenoses recognition is easy, but errors from perspective foreshortening, which can only be avoided by exact bronchoscopic measurements of length and diameter, must be carefully guarded against. As such measurements are indispensable in certain cases (dilatation, intubation, etc.), it is necessary to discuss briefly the method of their employment.

Any estimate of distances made with one eye—*e.g.*, the distance between the bifurcation and the lower end of the tube — is extremely unreliable for the reasons stated in Chapter II., even when the whole tract can be brought under lumen presentation. It is difficult even in lumen presentation to get any particular point of the wall on the same level as the end of the tube. In such measurements it is best first to pass the tube down to the lower end of the tract in question, and, on withdrawing it, to note the distance in centimetres on the graduated tube. In many cases it will be easier for the patient if the measurement is carried out with a metal sound, wool-carrier, or the like, with the tube high. Frequently it will even suffice to count the tracheal rings, whose distance can be deduced from the length of the trachea and the normal number of rings—*i.e.*, sixteen to twenty.

It is always difficult to judge of the length of a stenosis, because, without a presentation of the lumen, no accurate perception of the lower end of the contracted portion is possible. If the stenosis is quite impassable, it may be possible to obtain information regarding its length by palpation by means of a rigid olive-ended bougie. In the absence of such an instrument a very rigid wool-carrier with the wool well lubricated may be used.

For obtaining perpendicular projections of parts presented endoscopically on the outside of the chest, the "tracheograph," described on p. 206, is used. With it direct longitudinal measurements can also be directly performed.

In estimating the width of lumina and the like, the lumen of the tube which is introduced is frequently taken for comparison. When, however, the object measured is not quite close to the lower extremity of the tube, foreshortening must always be taken into account. If, for instance, the length of the tube (plus the distance of the eye from the upper end of the tube) amounts to 25 centimetres, then, if the object is 5, 10, or 15 centimetres distant from the lower end of the tube, the estimated size (as compared to the lumen) must be multiplied by $\frac{5}{6}$, $\frac{5}{7}$, $\frac{5}{8}$. In such cases the measurement of the object will be more satisfactory if it is compared with some immediately adjoining object—*e.g.*, the forceps, which is set, with the regulating screw, like a compass to the opening desired. Annular stenoses with firm walls are, of course, best measured by the aid of cylindrical bougies of increasing thickness.

The excentric contractions of deviating parts of the wall, which occur so frequently, are very difficult to measure, and, indeed, cannot be presented in lumen without changing their calibre. It is also hardly possible, without special measuring instruments, to determine with any precision expansions of lumen. Finally, it should be remembered that in interpreting the endoscopic image pulsatory and respiratory conditions (coughing) must be taken into account.

B. GENERAL PREPARATIONS.

In my bronchoscopic classes I am in the habit of discussing general preliminary preparation, such as asepsis, choice of tubes, preparation of operative instruments, etc., with reference to a series of typical clinical examples. But in this written account, leaving on one side everything clinical, I am obliged to treat the matter rather more generally, although, considering the variety of individual cases, there is a danger of being too general. In any case the first question to be settled is—

Upper or Lower Method?

The decision of this question is by no means merely a matter of personal endoscopic routine, but also a matter of clinical indication which must adapt itself to each individual case.

If statistics are consulted, it will be found that in Gottstein's series the upper method was followed in 37 per cent., the lower method in 37 per cent., and the two methods in 17 per cent. of all the cases, showing that upper and lower bronchoscopy were practised equally. The proportion is rather different when the numbers are taken with regard to different ages, as I have done in the following table:

Age in Years. (1)	Lower Bronchoscopy. (2)	Upper Bronchoscopy. (3)	Upper and Lower Bronchoscopy. (4)
	Per Cent.	Per Cent.	Per Cent.
0–6	47	33	20
7–12	32	53	15
13–60	24	52	24

It is seen that the frequency of tracheotomy after the age of six rapidly decreases, and after the twelfth year decreases still more. Of course the cases in the fourth column (upper and lower bronchoscopy) are not included. These belong nearly all to the second column, because, as the upper method is impracticable, tracheotomy had to be performed.

It must be remembered in the interpretation of these statistics that the cases in question were all of an operable character (foreign bodies), and that peroral introduction of the tube was often contra-indicated by the gravity of the symptoms. In many cases, also, it was only after tracheotomy had been performed that endoscopic treatment took place. Nevertheless, the percentage of lower bronchoscopy seems very high in comparison with the figures in Killian's clinic, but this no doubt is due partly to imperfect mastery of the method—which was still on its trial—and partly to an incomplete set of instruments. If the earlier difficulties of passing the larynx with a long and narrow tube and frontal illumination are remembered, it may confidently be expected that the lower method will be largely abandoned as the new instruments are introduced.

Nevertheless, lower bronchoscopy will in future continue to be practised in the case of certain indications, for it is not only technically much easier to carry out, but, in certain cases, also guarantees greater certainty and safety in endoscopic operation.

In practice three main groups of such cases have to be considered.

1. The subject may already have an opening in the trachea at the time of examination.

2. Tracheotomy may promise other than endoscopic advantages.

3. The incision of the trachea may simply serve the purpose of tracheo-bronchoscopy.

In the first case, of course, the lower method of examination will be contemplated only if the purpose is something else than to study the lumen image of the trachea in the neighbourhood of the tracheal opening.

In the second case it is more difficult to decide—*i.e.*, when for other reasons (laryngeal dyspnœa, etc.) the question of tracheotomy has to be considered. It is not only important to remember that lower tracheo-bronchoscopy is far more easily performed than the upper method (even a beginner is sure of success), but it must also be considered that even in the case of success it is possible that subsequent tracheotomy may become necessary, and this has often to be carried out with the greatest haste while the patient is exhausted and seriously affected with dyspnœa. There is also the consideration that, with the lower method, anæsthesia, which is dangerous in dyspnœic conditions, is avoided and the patient becomes less exhausted—a circumstance which especially deserves to be remembered when an examination has to be repeated or when endoscopic treatment is prolonged.

These considerations lead to the third case, in which tracheotomy would simply serve the purpose of the endoscopic examination or operation. By this I do not refer to the introduction of the tube, because I presuppose sufficient skill in this matter. Even in this case tracheotomy may be clearly indicated unless, owing to severe concurrent dyspnœa, an anæsthetic would be necessary, or if specially difficult endoscopic operations are in question. Among these, of course, are especially difficult cases of foreign bodies, when the form and size of the foreign body makes it uncertain whether it can be passed through the larynx, or when difficulties of presentation or loosening are anticipated, or when a moving body lies in front of the trachea, or when the operation is seriously imperilled through continuous irritability or secretion.

All this must especially be taken into account with children, for in their case the smallness of the parts seriously adds to the difficulty. There ought, therefore, to be no hesitation about resorting to tracheotomy when any special difficulties occur during the upper examination, or even when danger may be anticipated from cocaine or general anæsthesia, as is especially the case in children, owing to the undue prolongation of the examination. For operative bronchoscopic purposes in the case of infants the lower method alone is available.

In these general rules I have presupposed the mastery of bronchoscopy, or at least the successful introduction of the tube. If the beginner fails even at this stage, tracheotomy is absolutely indicated in serious bronchoscopic cases. The operation which, with adults, will always be effected with local anæsthesia involves only a minimum risk, and the dangers of breathing through the canula, and the difficulties of decanulation, are entirely avoided. It is therefore not right to endeavour at all hazards to avoid tracheotomy in favour of the more elegant upper method, or even to force the latter in a manner not favourable to the interests of the patient.

For the patient—apart from the demands on his patience and endurance—the length of time occupied by the endoscopic operation is most important. Indeed, it may be said that the dangers of bronchoscopy lie primarily in its duration, and that in cases which end fatally, if the method itself can be blamed, it is the duration of the examination which plays an important part.

The reasons of this are obvious. For one thing, danger from cocaine increases rapidly with the duration of examination, because, even when introducing the tube, the maximum dose is often necessary. Further, it must be noted that physical excitement, reflexes, and direct obstructions cause greatly increased demands to be made on the heart and breathing, and that in many cases the lungs are diseased, or the respiratory centre injured by prolonged dyspnœa, and this renders the patient unfit to cope for any length of time with such increased demands. If the operation is performed without an anæsthetic, an excessive prolongation of the operative shock, together with the two other drawbacks, may lead to fatal collapse.

When there is no danger in delay, it is better that a difficult bronchoscopic operation should be distributed over several sittings than that the duration of the tube introduction should exhaust the patient. Several carefully-considered examinations generally yield a better result than a single forced sitting. In this connection I call to mind the extraction, carried out by Killian and myself, of a bronchial foreign body* which extended over ten sittings, some of which attained the great length of two hours.

It is not possible, of course, to state a normal period or maximum period for the duration of bronchoscopic operations. As a rule the tube has to remain in its place from five to fifteen minutes. In one favourable case I was able to extract a bone from the right main bronchus in less than three minutes (counting from the moment when the tube was introduced).

Fortunately the dangers already enumerated, which are generally avoidable, are almost the only ones which are connected with bronchoscopy proper. In order to state the actual position, I give Jackson's statistics for ninety-four cases of upper and lower bronchoscopy of foreign bodies, with a mortality of 9·6 per cent. Six of these cases Jackson himself deducts because the examinations were undertaken on patients who were in such a condition that a fatal termination was to be expected. This leaves only 3·2 per cent., of which 2 per cent. occurred in children, which bears out what has been said above. These cases, as has already been stated, are concerned with bronchoscopic problems, the precise discussion of which no longer falls within the province of method. In the case of diagnostic introduction of the tube, danger is almost out of the question because in the hands of experienced practitioners perforation or infection are scarcely possible. The latter point requires a little further consideration.

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* *Zeitschr. f. Ohrenheilk. u. Krankh. d. Luftwege*, Bd. 55, H. 1.

Asepsis.

If it is remembered that there is comparative absence of danger even in cases of considerable injury to the lungs—apart from bleeding and pneumothorax—and also that exceedingly septic bronchial foreign bodies (*e.g.*, carious teeth), if extracted in time, do not leave any progressive suppuration, even if the bronchial mucous membrane is injured, it is evident that there is no serious danger of infection in the bronchi. The air-passages allow for the prompt removal of secretions, like a wound which has been thoroughly laid open, and this is only disturbed if the foreign body or the swelling caused by it more or less blocks the way. Only in such a case are the peripheral sections of the lung threatened with bronchitis, bronchiectasis, pneumonia, abscess, gangrene, and their consequences.

If this were not so, bronchoscopic asepsis would be very precarious, as it is absolutely impossible to pass a bronchoscopic tube aseptically through the mouth and equally impossible to exclude the aspiration of saliva into the air-passages treated anæsthetically. It is from this point of view that experiments on foreign bodies, such as I have carried out on voluntary subjects, should be regarded. Provided extraction is certain, there is scarcely more danger involved than there would be in placing the foreign body in the mouth.

Bronchoscopic asepsis may therefore generally be confined to employing the tube and forceps with washed hands after the former have been rendered aseptic. If the instruments have been infected with diphtheria, syphilis, tuberculosis, etc., the forceps should be boiled before being disinfected in the soap spirit solution. The parts of the electroscope which are accessible when in use may be thoroughly washed with soap spirit or with carbolic lotion. If anything more is desired, they may be disinfected with formalin-vapour, as used in cystoscopy.

It is generally superfluous to undertake a special disinfection of the patient, although cleansing the mouth, as recommended by Jackson—brushing the teeth and rinsing the mouth every two hours with 30 per cent. alcohol—is undoubtedly valuable. This applies especially in all cases of infectious mouth diseases or granulating wounds in the upper air-passages. For then the slight degree of virulence of most bacilli contained in the normal secretion of the mouth is increased to its utmost, as is well known, even in slight cases of angina and catarrh. Jackson rightly advises that a tube which has been used in upper tracheoscopy should not be passed through a tracheal fistula without being sterilized afresh. In the case of tracheotomy wounds, while secondary healing is in process, sterilization with hydrogen peroxide or tincture of iodine should be effected before the tube is inserted.

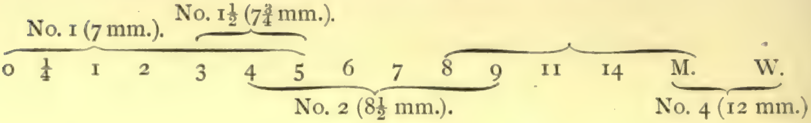
Personal asepsis should be observed by the practitioner, as in other cases. Special cleanliness is desirable in twisting the cotton-wool round the wool-carrier.

Choice of Tube.

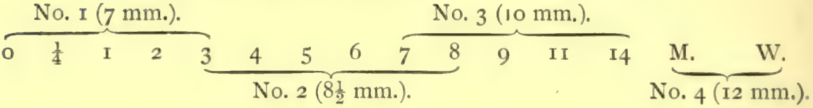
When using my extensible bronchoscopes, it is merely the thickness of the tubes which generally determines the choice, so long as the rule is observed that every size of bronchoscope whose spatula tube has to pass the larynx must have an extensible tube of a size which will permit it to penetrate into the main and stem bronchi. It follows from this that the same dimension of tube must be employed in tracheoscopy as in bronchoscopy.

In order to afford a convenient guide with regard to the thickness of tube suitable for various ages of patients, I add the following table of the four dimensions of tubes with the respective ages:

I. Upper Tracheo-Bronchoscopy.



II. Lower Tracheo-Bronchoscopy.



From this table it can be seen that for some ages various sizes of tube may be suitable. In the case of children it will be better to take the larger size, because with them the field of vision is anyhow very small. On the other hand, they are good subjects for autoscopy, and the larynx is very capable of expansion. With adults, however, and those approaching the adult age, it will be preferable to take the smaller size, on account of the capacity of the tube in displacement and change of position. But after all the choice must always depend to some extent on the endoscopic routine of the practitioner and the subject's capacity for endurance and general fitness for autoscopy.

Table I. also shows that in employing the four ordinary sizes considerable compromises must be made, because of the very various physical development at the ages which correspond to each thickness of tube. This applies especially to the thinnest size which properly corresponds to the age between one and three years. Consequently, No. 1½ (7¾ millimetres) already mentioned, should be obtained to complete the set, as this is more suited for the ages from three to five years than Nos. 1 and 2 (see table, I.). For the intermediate age—nine to ten—no special supplementary instrument is necessary.

In lower tracheo-bronchoscopy (see table, II.) these difficulties have not to be met because the introduction of the tube is very easy, and the opening may, if necessary, be enlarged. For this reason the usual limits of the suitability of the four sizes are placed somewhat lower.

In all tracheo-bronchoscopic practice it should be a rule to have both or one of the adjoining numbers in readiness, so that in a given case the tube can be changed without loss of time. If the tubes have been boiled just before examination, the operator must not forget to remove the drops of water with a cloth.

It is advisable at once to prepare the electroscope for the tube intended to be used (regulation of the intensity desired, centring of the projection, focussing of the condenser). All that is necessary on this point was said in Chapter II. A damp and a dry rag should be kept in readiness for cleaning the mirror. When operating away from home, a reserve burner should always be carried.

Instruments for Operations, etc.

In preparing the bronchoscopic instruments, the main point to be regarded is their length and end pieces. In order to determine the suitable length of each case, the table on p. 136 should be taken as a guide, and 10 per cent. added to the value found. If the table is not available or applicable (as in the case of children), the patient's head should be extended, a measurement taken of the direct distance between the upper row of teeth and the middle point between the sternal ends of the second and third ribs, and 10 per cent. added. For measurement the simplest instrument is the extensible bronchoscope, on the spring of which the length can be read in centimetres. (The lengths registered on the bronchoscope are measured exclusive of the tube funnel, which is about 3 centimetres long, so that this must be added when the forceps is applied. The length of forceps is reckoned as the distance from the catching end to the upper bend.)

In case of doubt it is better to use a forceps a few centimetres too long, because the distance of the lamp leaves 10 centimetres scope, and with the new electroscope the work can be done with any length of forceps. When there are two forceps, they should be arranged for somewhat different lengths, but they should not be fitted with end-pieces until it is known what variety is likely to be required. The question of selection, when the foreign body is known, is referred to on pp. 45 and 46. The assistant should, if possible, be familiar with the mechanism of the forceps, so that in case of need he may modify its length during the operation. This should not, however, be necessary if the rules given are observed.

The instrument set should include hooks. These prove so useful, especially with foreign bodies and needles, that they should be always kept at hand. The shaft may be bent (in a direction opposite to the hook) just before it is used.

In any case it is necessary, before beginning bronchoscopy, to have in readiness the means for cleaning the field of vision—viz., a saliva-pump and wool-carrier. The smallest of the three pump-tubes (25 centimetres) should be used for tracheoscopy and lower bronchoscopy in children, the medium one (35 centimetres) in bronchoscopy for adults. The wool-carriers are employed, according to the length required, either singly or screwed together. A sufficient number should be got ready before the tube is introduced, and the cotton-wool twisted on according to the width of the tube used. In certain cases a cotton-wool swab dipped into a solution of adrenalin must be kept ready. When there is much expectoration, the field of vision has to be kept clear by wiping the inside of the tubes from time to time. In extreme cases it may even be necessary to withdraw the extension tube and to clean its outside. The best way to do this is by using pieces of gauze which are pushed through the tube with the wool-carrier.

As further aids in operative bronchoscopy, mention must be made of preparations for inhaling oxygen, strong stimulants (adrenalin), narcosis, and tracheotomy. On the instrument table there should also be cocaine (20 per cent. and 10 per cent.), adrenalin, and liquid paraffin, or some other preparation to lubricate the tube.

An assistant may, if necessary, be dispensed with in purely diagnostic tracheo-bronchoscopy when the patient is in a sitting position, but this does not apply where tracheotomy is concerned or a general anæsthetic is used. When operative measures are adopted with the patient lying down, an assistant must be present if only to support the head. If there is a second assistant, he should be entrusted, according to his abilities and the nature of the case, with arranging and watching the patient, or with looking after the instruments (screwing on of forceps joints, lengthening or shortening, cleaning, handing to and taking from the operator). In the absence of a practised assistant, all this can be done by the operator, provided that everything that may be required is prepared beforehand, and is arranged on a low instrument table on the right-hand side. But on no account should a difficult endoscopic case, which may necessitate the inhalation of oxygen, anæsthesia, or even tracheotomy, be undertaken without sufficient well-trained assistants.

The position of the assistants when the patient is lying down necessarily follows from the rule that the head must be held from the right side, and the instruments served from the same side, whereas oxygen, anæsthetics, etc., are administered from the left.

Not until all these preparations have been carried out, so far as the particular case requires, and until all the instruments and appliances have been tested and placed handy, should cocaine be administered. This should be followed immediately by the introduction of the tube, as from that moment every minute is precious.

C. LOWER TRACHEO-BRONCHOSCOPY.

1. General.

The examination of the air-passages by means of straight tubes can also be undertaken through high or low tracheotomy wounds. As far as the selection of the operation is concerned, high tracheotomy is preferable, since it is easier to perform, the danger from surgical emphysema is certainly less, and the trachea lies much nearer the surface.

At the level of the sternal notch, the trachea lies fully 5 to 6 centimetres from the surface and so the deep wound necessary to reach it will meet it at a sharp angle.

The mobility of the trachea is thereby greatly impaired, and the possibility of bringing it into line with a tube which has been introduced is almost completely lost, so that no advantage is gained by pursuing the investigation by this method. If the tracheotomy is performed solely for the purpose of the examination, it is advisable to proceed with endoscopy as soon as the operation is completed. It is then not only possible to take advantage of the anæsthesia (general or local) induced for this purpose, but there is also the further advantage of an aseptic wound and an uninflamed trachea. The examination taxes the patient's strength so little that a thorough investigation can be made.

For a few days after tracheotomy the conditions are very unfavourable for the introduction of the tube. The infiltrated edges of the wound and the purulent track of the wound itself are painful and possess little mobility. Tracheitis and bronchitis may almost suppress the action of the cocaine, while the increased secretion, the inflammatory injection, and the obliteration of the usually well-defined rings diminish the field of vision and render orientation difficult.

Old-standing tracheotomy wounds do not offer the same advantages as a recent operation, since prolonged breathing through the tube almost always sets up some inflammatory condition of the mucous membrane, and is apt to produce sensitive points in the neighbourhood of the wound.

Fortunately, it is not necessary to use much cocaine for the lower method so that it can be carried out in most cases quite safely and without inconvenience.

There are no contra-indications to the method, except those connected with the tracheotomy. The existence of pneumonia in a case where a foreign body is suspected is an indication for, rather than against, the examination.

ANÆSTHESIA.

Immediately after the operation of tracheotomy, when the mucous membrane is normal, a view of the trachea can often be obtained by simply dropping a few drops of 10 per cent. cocaine solution, with adrenalin added, into the tracheotomy wound. Contact with the smooth surface of the tube produces no pain in the trachea when the latter is not inflamed, and it is only in the subglottic space and at the bifurcation that there is any considerable irritability.

It is, of course, more satisfactory to use the painting syringe, always beginning in the immediate neighbourhood of the wound, and not neglecting the anterior wall though this is difficult of access. In the case of persons who have a permanent tracheotomy-tube, there are always obstinately irritable points in the region of the wound. If these are overlooked, the real seat of the reflex cough when the tube is introduced is apt to be missed, and the bronchial tree is flooded with cocaine to no purpose.

The middle section of the trachea may be passed over rapidly, but the irritable points at the bifurcation need a longer application. This can easily be done by feel without introducing the tube. The right main and stem bronchus can be reached with certainty by feel with the cocaine swab if an oblique direction is taken from the right side of the throat to the left. For the left main bronchus painting by feel is less advisable, because this arises at a sharper angle and is not so easily found, and the straight brush has to press too much on the medial wall of the bronchus. Still, it is permissible to use the brush-syringe by feel when it is important to limit as much as possible the length of time the tube is introduced.

Of course, the application of cocaine by feel must be avoided in all cases when the brush might cause injury, especially when a foreign body is suspected. In such cases only the immediate neighbourhood of the opening in the trachea is rendered insensitive, after which the tube is introduced and cocaine applied (with the lamp in the high position) under control of the eye, gradually and only as far as the eye can see. If foreign bodies or doubtful points are met with, direct contact with the brush should be avoided and some cocaine should be dropped in by pressing the syringe.

In normal conditions a 10 per cent. solution (5 per cent. with children) suffices, but it is better to use a 20 per cent. solution when there is any tracheo-bronchitis. The solution must be spread equally over the whole surface of the mucous membrane, because inflammation renders parts which are normally almost insensitive extremely irritable. I once had to deal with a case of bronchiectasis with incessant cough and expectoration where even large amounts of cocaine did not succeed in allaying the irritation, and was obliged, although practising lower bronchoscopy, to make use of all the expedients mentioned in Chapter III.

In judging of the degree of insensibility obtained, it is not possible to be guided altogether by the effect produced by touching with the brush, because, as already stated, equal pressure with the thick tube causes much less irritation. If, in the course of examination, irritability returns, or if the cause of persistent irritability is not evident, the various irritable points ought to be tested one by one—viz., the neighbourhood of the tracheotomy wound, the bifurcation of the trachea and deeper divisions of the bronchi. In the inflamed surroundings of a foreign body, it is, indeed, frequently impossible to attain complete insensibility.

POSITION.

Lower tracheo-bronchoscopy is most easily and conveniently practised when the patient is sitting, but the position will depend on the special circumstances of the case. Patients on whom tracheotomy has recently been performed or who are feeble will best be examined lying down. Where foreign bodies are concerned, the lying position is generally preferable, because of the possibility of the patient falling back; but it often happens, especially in chronic cases, that patients suffer less from cough irritation when they are sitting up. If dyspnœa persists after tracheotomy, the examination is generally easier for the patient if he sits up, whereas operations of longer duration render the "passive" lying position more desirable.

In the case of patients with a permanent tracheotomy-tube, the sitting position is advisable unless there are any contra-indications. Children are better treated lying on their backs as they cannot be depended upon to keep quiet of their own accord. Of course, examinations of the portion of the trachea above the tracheotomy wound can only be carried out when the patient is lying down.

For examination when sitting, any chair, with or without a back, can be used. In the lying position, a high table or horizontally-placed surgical table, if possible without a raised head end, will suffice. The patient must be put in the same position as for tracheotomy—viz., he must lie on his back and extend his neck. This position is most easily secured by placing a roll under his neck. Greater mobility is obtained when the head hangs over the edge of the table; in this case an assistant can support it, and bring it into the various positions required.

2. Procedure.

Preliminary Remarks.—The beginner is urgently advised to make his first bronchoscopic observations on a person with a permanent tracheotomy-tube. This is not only an excellent introduction to bronchoscopy but supplies many useful lessons for minor operative procedure. Persons with permanent tracheotomy-tubes should always be examined endoscopically at regular intervals as they nearly all suffer from occasional erosions, ulcerations, granulations, etc. The timely treatment of these conditions by cauterization, removal, or alteration of the shape of the tube, not only removes the trouble promptly but also prevents more serious complications such as scar formation or erosion of the cartilage. Such a patient may be taken as an illustration of the present procedure.

After all preparations are complete, the room sufficiently darkened, the right tube attached, and the light regulated, the instrument should be smeared with liquid paraffin, and warmed over a spirit-lamp sufficiently to prevent the expired air condensing in the tube. The mirror of the electroscope should also be warmed slightly unless the lamp has been burning for at least a minute.

TRACHEOSCOPY.

For this operation the patient should be in a sitting position. While the tube is being introduced, it should be held almost horizontally at first, while the operator looks past the sloping end from the outside and examines the track of the wound and determines his direction. During this process any existing obstacles to introduction are generally noticed, such as laterally projecting swellings which contract the tracheotomy opening to a perpendicular slit. These may usually be overcome by inclining the wedge-shaped end of the tube a little. Wound retractors are scarcely ever required even in new cases, and the open sloping tube is generally introduced more easily when no mandrin or dilator is used. It is only when it is desirable to dilate old-standing tracheal wounds that such expedients need be considered. If the procedure is followed according to the directions given, and this is done slowly, a considerable degree of dilatation may be effected without any hæmorrhage.

When all the external surroundings of the wound have been defined the tube may be introduced a little way, while the operator looks through the aperture of the mirror and pushes the tube forward, by means of slight rotatory movements, to the vicinity of the posterior tracheal wall. Not until then should he turn it more vertically, while he draws it forward with a corresponding pull, during which process, as a rule, a considerable section of the trachea, or even the bifurcation, is presented. There is no difficulty in the way of pushing it farther forward, but for the present I wish to deal with the neighbourhood of the tracheal wound, as this examination is of great practical importance (difficult decanulation, trouble with the tube).

The presentation of the posterior tracheal wall is very easy, in fact, is automatic. The lateral walls, too, can easily be brought into view if the tube is held more or less horizontally and its end displaced sideways. The presentation of the anterior tracheal wall immediately below the wound is somewhat more difficult. The patient must turn his face on one side so that the tube may be placed exactly in the middle line. If this movement is repeated with a strong forward pull, while the tube is at varying depths, a more or less surface view of the anterior wall is obtained.

The examination of that portion of the trachea which is situated above the tracheal wound (retrograde tracheoscopy or direct lower laryngoscopy) is, of course, only to be undertaken with a patient in the lying position. In such a case the same principles of displacement apply, but the presentation is far more difficult and it not infrequently happens that the operation fails altogether when the tracheotomy wound is situated high up or is very narrow.

There is also the further difficulty that, in cases of laryngeal stenosis or of narrowness of the tracheal wound, the tube may completely fill the canal of the wound, and this will naturally cause an interruption of breathing. Even when very thin tubes are used — preferably the "tracheal funnels" (Fig. 86, p. 216), described in Chapter VI.—success is not always assured.*

The direct lower examination of the region of the tracheal wound, as may be seen from the description, can only yield surface images. If, as in many cases of difficult decanulation, a lumen picture of this region is required in order to afford a complete interpretation, and if the result of the speculum examination proves unsatisfactory, direct upper tracheoscopy must be used.

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* Even before direct methods were employed, the expedient was tried of introducing a small speculum into the tracheal wound, possibly widened by the speculum itself (indirect lower tracheoscopy), a procedure which, in fact, may afford useful views of the subglottic space.

Nitze's cystoscope (salpingoscope), reduced by Valentin Hirschmann for the examination of the naso-pharynx, was first employed by Wild for endoscopy of the subglottic space where the tracheal wounds were very narrow, and in this way he discovered granulations. I myself, when employing the same method, came to the conclusion that the excessive foreshortening of cystoscopic images scarcely admitted of a correct interpretation of the lumen images. The upper edge of the tracheal wound looks more than life-size while the rima glottidis is reduced to a small chink. Foreign bodies or striking alterations can always be ascertained.

After an inspection of the neighbourhood of the opening in the trachea, a return is made to lower tracheoscopy, and the lumen image of the trachea is examined with the tube high. If necessary, considerable displacement may be employed in order to get a view down to the bifurcation. While this is being done, the anatomical and physiological phenomena described in Chapter V. should be noted, a clear idea of the perspective relations of the wall image and lumen image obtained, and the normal conditions of form and colour observed.* It is interesting to observe the extent to which the brightness of the field of vision depends upon the degree of injection of the mucous membrane, the colour of which in various patients may be anything between a yellowish-pink and a dark bluish-red, which often quite conceals the rings which are usually so clearly marked. If the wall is blanched by the application of adrenalin the brightness is almost doubled.

The advance of the tube toward the bifurcation proceeds quite naturally while lateral movements constantly indicate the distances. These should also be checked outside from time to time by the tube scale. Above all it is advisable, especially for a beginner, to keep a watch on the outer end of the tube which may slip down unperceived while the operator vainly feels for the bifurcation when the tube is already in the stem bronchus. A rule should be made, therefore, never to enter the bronchi without having previously presented the bifurcation as this often lies in an extramedial position.

BRONCHOSCOPY.

When the main bronchi are presented, the direction of the tube deviates from the medial line and approaches as near as possible to the direction of the bronchi. This of itself determines the position of the patient's head, who always looks towards the bronchus which is being examined (see Fig. 60). When the lower method is used, the presentation of the lumen of the main bronchi does not require any considerable displacement of the bifurcation, because, owing to the great mobility of the point of introduction, the tube may take a very oblique direction. It is a mistake for the patient to hold his head back rigidly as this impedes the mobility of the trachea.

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* I have refrained from reproducing endoscopic images in this book. Their didactic value seems to me rather small, as drawings are always characterized by great subjectivity, and on account of the narrowness of the tube there is always a question of combined images. Nor can endoscopic photography, of which I shall speak elsewhere, take the place, for the beginner, of a direct view of normal conditions.

When the lumen of the right main and stem bronchus is presented, a view of the bifurcation of the lower lobe bronchi is usually obtained; indeed, if the illumination is good, the white bifurcation ridges of the tertiary bronchi at the bottom of the lower lobe branch may even be seen. This picture, however, changes very easily, as the slightest movement of the tube will cause other branches to be presented in the depth of which fresh ridges become visible. Even the movement of respiration often suffices to produce a rhythmical alternation of the images.

When the lumen of the right main bronchus is presented with the tube high, the upper lobe bronchus, and generally also the middle lobe branch, are as a rule concealed from view. The former, in particular, requires considerable displacement in order that the wall may be presented. The end of the tube should first of all be brought to the level of the bifurcation, and then advanced laterally about 1 or 1½ centimetres at the very most. Vigorous pressure against the lateral wall will generally reveal the lower edge of the upper lobe branch faintly protruding into the lumen (see Fig. 59*b*, II., p. 160, and Fig. 60). In the latter figure the beak of the tube is wrong, as the operator stepped aside for the photograph to be taken.

If the upper lobe branch is not successfully discovered in this way, the following procedure will frequently serve the purpose: The tube is first pushed a little farther into the stem bronchus and withdrawn slowly with strong lateral displacement. It will generally be seen that the ridge of the upper lobe branch suddenly appears in the field of vision standing out clearly against the ring markings.

In lower bronchoscopy, the right upper lobe bronchus may, indeed, always be presented sufficiently to render visible the lower circumference of its first or first and second rings, but this depends very much on its direction and mobility. Frequently presentation oscillates rhythmically in consequence of respiration, and if the bronchi are much displaced, abnormal respiratory displacement is produced.

It is never possible to obtain a presentation of the lumen of the upper lobe branch by direct means, although in one case Killian succeeded in pushing the tube as far as the first point of division. If a plane mirror is introduced into the tube at an angle of 45° as was done by Killian, it should be possible, in favourable conditions, to view the lumen. These conditions, however, can only occur when the angle of inclination of the mirror accidentally coincides with the varying direction of the bronchus, as its minimum field of vision is constant. The same is true of the very feeble illumination afforded by the tiny mirror. For this reason the method cannot be adopted in practice.

The conditions are much more favourable with cystoscopic illumination by means of an internal lamp, because such instruments may easily afford an angle of 60° for the field of vision, and this makes the direction of the bronchus immaterial. I have therefore occasionally used Löhning's gastroscope and obtained a perfect lumen image both of the right and left upper lobe branch. In the former case, presentation succeeded with each to such an extent that I was able to demonstrate the ridge at the primary division, and the two tertiary bronchi.

The process of examination is as follows: A simple tube with a lumen of at least 11 millimetres (the diameter of the gastroscope is 10 millimetres) is introduced without lateral displacement as far as a point immediately above the point of deviation of the bronchi. If the end of the tube is sloping, it is directed medially. The gastroscope, with its light burning, is then placed in the tube, the closely-fitting wall of which at first renders the field of vision completely dark. Only when the gastroscope lamp gets beyond the end of the tube is the field of vision lighted up. One or two very magnified bronchial rings are seen and only slight movements are required to present the edge or the lumen of the diverging bronchus. Of course the gastroscope may be introduced without a guiding tube, but this makes it much more difficult to find the point of divergence of the bronchus, as the magnified wall image of the trachea and of the main bronchus affords no means of orientation.

Owing to the long focal distance of gastroscopes—especially in Kautsch's instrument—the foreshortening is quite moderate, and it is easily possible to see the lumen and to recognize any foreign bodies or other abnormalities. On the other hand, the relatively great distance between the prisms and the incandescent lamp is a drawback, as the short distance of the object and the smallness of the branching bronchus may stand in the way of a simultaneous presentation of the light and the field of vision. It is therefore particularly advisable that an endoscope which is specially intended for bronchial examinations should have a smaller diameter (about 8 millimetres), and as short a distance as possible between the incandescent light and the prism. The length should be about 30 centimetres when the instrument is to be used both for upper and lower bronchoscopy. (Such instruments are supplied by F. L. Fischer, Freiburg in Breisgau.)

It is doubtful whether endoscopy of the upper lobes is of much practical value. At the same time it should be remembered that foreign bodies may be observed in the upper lobe bronchus (Wild), though they might be missed in examination by the direct method. Goldstein also mentions cases in which a foreign body was missed during bronchoscopy, most probably because it was in the upper lobe branch. Killian has pointed out that upper lobe bronchoscopy may be of service in determining the point of origin of tuberculous sputum.

It is easy to effect the direct presentation of the lumen of the middle lobe bronchus if moderate forward displacements are used while the tube is gradually advanced. It must, however, not be forgotten that the direction of origin has frequently a more lateral course, and this may easily give rise to confusion with the lower lobe branches. In doubtful cases it is always advisable to return to the bifurcation and to examine the side-walls of the stem bronchus progressively, constantly checking the distance by means of the scale.

The divisions of the lower lobe region are very variable, but generally the prolongation of the stem bronchus is as easily revealed as the lower lobe branch itself.

While examining the left bronchial tree, the sharper angle of origin of the main bronchus is noticeable and its lumen can only be presented by means of considerable displacement. The powerful pulsatory movements of the pulse, due to the pressure of the arch of the aorta, are communicated to the tube and will easily be felt. With the lower method it is always easy to get into the main bronchus, but care should be taken to see that the end of the tube does not press against the medial wall of the bronchus and the tube should only be moved forward after presenting the lumen as completely as possible.

Strong lateral pressure, together with as oblique a position of the tube as possible, are required when the left upper lobe branch is to be presented. Its point of origin must be looked for on the lateral wall at a distance of 4 to 5 centimetres from the bifurcation ; this distance should be checked by the scale on the outside tube. Sometimes it is not possible to obtain a presentation even when employing the retrograde method used for the right upper lobe bronchus, and the surgeon finds himself in the adjoining branch which serves the lower lobe. Here the direct continuation of the stem bronchus presents itself as the real lower lobe branch, at the end of which a variable image of tertiary subdivisions may become apparent. An inspection, by means of displacements in all directions, of the various lateral branches which arise monopodically, and whose width of lumen often nearly equals that of the lower lobe bronchus, should not be omitted.

It should be made a rule to present the various bronchial branches in the reverse order when withdrawing the tube. In this way, not only are occasional errors revealed, but, as I pointed out in connection with the upper lobe bronchus, it is possible that side-branches which have been previously overlooked may come suddenly into view.

Lower tracheo-bronchoscopy is so easy that even at a first attempt anything of importance can hardly be overlooked. It is true that a beginner will at first be confused by the number of ridges at the bifurcation which come into view in the lower section of the stem bronchi, especially as, owing to the differences of depth not being very apparent, the various branchings appear to lie more or less in the same plane. Parallactic displacements, such as may easily be produced by means of regular lateral movements of the tube, will reveal differences of elevation, and continuous presentations of the walls on all sides will guard against important bronchial branches being overlooked. If now and then the meaning and names of some branches remain in doubt, this does not much impair the result of the examination. The following rule has always to be kept in mind: Bronchoscopy must never be regarded as satisfactory until the two main bronchi, the stem bronchi, the right middle lobe bronchus, and the two lower lobe branches, have been presented. Fortunately, the upper lobe branches do not play any important part—at least, in the treatment of foreign bodies—because, as is well known, these generally take the easier path through the main bronchus, stem bronchus, and lower lobe branch, having a decided preference for the right side as the path to it is more direct. It must also be stated that foreign bodies are generally arrested in branches of the first order and less often of the second order, probably because small bodies are usually coughed up at once. A few words, however, will be added on the examination of the tertiary bronchi.

The spatula tubes for lower bronchoscopy are of such dimensions that the usual sizes, both as regards length and diameter, can only be introduced into the main and stem bronchi. The branches to the middle and lower lobes may usually, by suitable displacement, be so presented in lumen that they can be seen clearly as far as the points of their division into the tertiary bronchi. If it is intended to examine the latter more closely, it is sometimes not possible to avoid introducing the tube into the secondary bronchi. For this purpose the smaller sizes, with corresponding extension tubes, should be used. Illumination and orientation are rendered more difficult by the restricted field of vision, but yet it is possible, especially in the region of the lower lobe, to get a good light on bronchi of the third order.

When illumination and sight fail, a clue may often be obtained by means of feeling with the probe. This important expedient must not be neglected even when visual inspection is possible, as at a great depth, or when there is a stenosis, the ridges at the bifurcation, clots of blood, or whitish secretion cannot be clearly distinguished from dark or mucus-covered foreign bodies. Killian has developed a typical procedure in the bronchoscopic application of probes to peripheral regions of the lungs, and has shown its importance in the surgery of the lung.*

For lower tracheo-bronchoscopy on patients lying down, the same rules apply as for the sitting position, though it will be found that orientation is much more difficult and that the tube has a smaller range of movement. The proper degree of extension (aided by a sand-bag under the neck), the turning of the head, and the proper height of the table and stool, have especially to be kept in view. If the lower end of the electroscope handle comes in contact with the thorax—which may occur if the patient has a very prominent chest—a rather longer tube must be used.

As regards the position of the electroscope, the general rule applies that in every kind of examination it has to be directed sagittally to the patient. There are exceptions, however, when the sloping spatula tube is used, as the position of its sloping end determines displacements. The causes of imperfect illumination are summed up on p. 24.

The manipulation of the electroscope is important in connection with cleaning the field of vision and using instruments. The surgeon must accustom himself from the first to turn the lamp on one side (always to his own left) in time, when cough threatens. If the electroscope stands horizontally, he should turn it upwards. Even when there is constant coughing and expectoration, he may, by clever manipulation of the mechanism, protect the mirror from being soiled as easily as a head-light. Any measures likely to provoke coughing, such as the use of cocaine or a swab, must of course be applied while the lamp is turned aside.

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* Chirurgen-Kongress, 1905.

Pump-tubes, only the shortest of which are used in lower tracheo-bronchoscopy, are employed either by feel, with the lamp pushed to one side, or under the control of the eye, with the lamp in the high position. In any case gentle dabbing movements are performed with the pump-tube covering the whole field of vision and possibly also the interior of the tube. Wool-carriers are generally used like operating instruments—viz., with the lamp high. During such manipulations, care should be taken that the instruments are passed on the right side of the mirror-holder, unless the slot in the mirror is used. Left-handed people experience some difficulty if they cannot use the left eye for looking through the hole in the mirror.

The length of the surgical instruments, when practising the lower method, will naturally be about 5 centimetres longer than the tube spatula. When there is no instrument at hand which is short enough, the work must be done through the slot in the mirror cleft.

The modifications of this procedure, which are required in the case of children, are mentioned in Chapter VI.

D. UPPER TRACHEO-BRONCHOSCOPY.

1. General Observations.

It has already been indicated that far greater difficulties are presented by the upper method as compared with lower tracheo-bronchoscopy. The reason of this is, in the first place, that the introduction is more complicated, and the larynx has to be passed; secondly, that the tube is not only much less mobile, but at the same time longer; and, thirdly, that the patient is inevitably inconvenienced, and the examination must necessarily be completed as quickly as possible.

It is a peculiarity common to every kind of direct examination that its difficulties vary to a great extent with each case, and this is more especially the case in direct upper tracheo-bronchoscopy. Whereas, on the one hand, a brief diagnostic glance in the case of a patient in the sitting position, who is particularly tolerant and easy of examination, presents one of the simplest problems, on the other hand, the treatment of a case of a chronic foreign body may make such extensive and varied demands on the operator as perhaps occur in no other surgical operation. In such a case it is necessary to be cautious and to keep within permissible limits while proceeding without hesitation. It is a question of combining the application of force with manipulative skill of an unusual kind, and of controlling the behaviour of the patient and of the technical apparatus with equal certainty. If, besides this, the haste required and the danger which may result from a moment's delay are considered, my reason for laying stress again on the value of careful preparation will be understood.

Upper bronchoscopy should be preceded by a detailed preparation carried through with pedantic thoroughness, in order that it may proceed swiftly, calmly and without interruption. The tube should be introduced immediately after the use of cocaine, and, though hurry must be avoided, the duration of endoscopy must be reduced to a minimum, and all unnecessary repetition omitted.

The necessary preparations include not only the complete mastery of the instruments, but also some practice in direct laryngoscopy and lower bronchoscopy. The practice of the upper method consists simply in combining these two, and even a beginner, if he has mastered them, may attempt the procedure with confidence. Apart from abnormal anatomical conditions, the upper method of bronchoscopy is always applicable; and fortunately it is possible, by means of those tests which were mentioned for direct laryngoscopy, to determine to some extent beforehand the very variable degree of practicability, so that an easy case may be selected for a first experiment. The indications for direct tracheoscopy vary within wide limits.

It scarcely needs to be pointed out that children are not suitable subjects for a beginner. I must also state that examination is by no means always facilitated by general anæsthesia, if only for the reason that upper bronchoscopy, like all direct methods of examination, succeeds much easier when the patient is sitting than when he is lying down.

As regards contra-indications, reference may be made to what was said in Chapter III. It may be added that there is no absolute contra-indication for foreign bodies present in the bronchi. Even pneumonia or other acute pulmonary affections cannot be so considered, because their only certain cure demands the extraction of the foreign body. This, of course, is not opposed to the fact that in chronic cases of foreign bodies general treatment, or treatment of the lung trouble, may bring about more favourable conditions for endoscopy. A rule should be made, when there is the least suspicion of a foreign body, to do too much rather than too little. It is well known that clinical phenomena may at first be quite absent, while the chances of extraction diminish from day to day.

ANÆSTHESIA.

The general method of local anæsthesia has been fully explained in Chapter II., so that I can confine myself here to a short description of special technique, while referring the reader to Chapters III., 2, and V., 1. Local anæsthesia in upper bronchoscopy is only a combination of the procedure in the lower method and in direct laryngoscopy with regard to the application of cocaine.

The latter is applied in the typical way, and includes, of course, the vocal cords and the subglottic space. After treating these, an attempt should be made gradually to straighten the brush, and to reach the upper portion of the trachea, and especially, by indirect means, the peculiarly irritable posterior wall.

The further treatment of the trachea, and even of the main and stem bronchi, with cocaine can be effected by Killian's method without the employment of endoscopic tubes. The head should be considerably extended, and the straight, rigid cocaine swab introduced from the corner of the mouth and passed through the glottis under guidance of the laryngeal mirror. As, for this purpose, a more or less considerable forward displacement of the epiglottis and root of the tongue is required, the employment of the long and thin painting syringe is often useless as it is too flexible. I am therefore in the habit of bending it forward a little at the end, to facilitate its entrance into the trachea without employing much displacement.

An attempt should always be made to apply cocaine by feel in the trachea as far as the bifurcation, if possible, because the patient is much less inconvenienced when he coughs by the thin, flexible stem of the syringe than by the thick, rigid tube. I must utter a serious warning against injecting cocaine into the trachea. It runs unnecessarily into the delicate branches of the bronchi, increases the dose and especially the extent of the absorbing surface, thus adding to the danger of cocaine-poisoning, which has always to be taken into account even when bronchoscopy is of short duration.

If anæsthesia of the trachea by palpation fails, or is only partially successful, it must be performed by sight with the tube. I myself proceed as follows: I introduce the long tube of my painting syringe, on the end of which a cotton-wool swab has been fixed, into the larynx presented with the autoscopy spatula, then remove the spatula, and afterwards attach the syringe filled with cocaine to the tube. It is then possible to paint the trachea, and especially its bifurcation, controlling the amount of cocaine used without much discomfort to the patient. If the thoracic vertebral column is bent laterally, it is easy to reach down into both (or at least the right) main and stem bronchi, and to apply cocaine as far as is necessary for endoscopy. If there is great irritability or increased expectoration, the patient must of course be given time before the process is repeated.

This palpatory method is by far the less distressing for the patient, but its application demands a certain amount of routine. If difficulties occur, the purely endoscopic procedure must be resorted to, introducing the spatula-tube into the trachea, and handling the brush like a surgical instrument under control of the eye with the lamp in the high position. Of course this is the only permissible way in all those affections in which blind painting is unsuitable, and this is especially so in the case of foreign bodies.

The trachea and bronchi require only slight quantities of cocaine when the mucous membrane is not inflamed, and in such cases a 10 per cent. solution will suffice. With adults, however, a 20 per cent. solution, applied sparingly, is preferable, because the object is the more speedily attained. Unfortunately, in cases of great irritability the higher degree of concentration is unavoidable.

It has already been mentioned, when discussing the lower method, that normally it is the bifurcation which especially requires cocaine. It must not be forgotten that the pressure of the thick tube is much more easily endured than the light touch of the brush, and that cocaine takes some time to produce its effect. Introduction may usually be begun before the reflexes evoked by the swab have quite ceased.

The laryngeal reflexes are by far the strongest of any in the air-passages. They therefore require the largest doses of cocaine, and are also the first to return when bronchoscopy is continued for some time. As long as the tube remains in position, this is, indeed, not very noticeable; but if it has been taken out—say to let the patient recover himself—and it is then introduced afresh, it is often found, even after a quarter of an hour, that the anæsthesia of the larynx has ceased to be effective. For this reason it is therefore preferable, if possible, to carry through bronchoscopy without interruption; but, with children especially, the danger of too long continued examination must be kept in view, and in all cases, if there is no urgency, a second examination can be made on the following day.

When local is to be combined with general anæsthesia, it should, if possible, be performed after the latter, although the autoscopic application of cocaine is then more difficult, the method by palpation not sure, and the patient is not able to spit out the excess of cocaine. The consumption of cocaine is smaller, in spite of these disadvantages, than when general anæsthesia is induced only after the larynx has been cocainized, the effect of the latter being then more or less lost. It may not infrequently happen that the decision to apply cocaine is arrived at only after the first abortive attempt at introduction. If in this attempt large quantities of cocaine had been used, it may be advisable in non-urgent cases (especially with children) to put off the examination altogether, and then begin straight away with general anæsthesia.

Both for the autoscopic application of cocaine and the introduction of the tube, anæsthesia ought to be very profound, because mere superficial anæsthesia increases irritability. Once the tube is introduced, chloroform should be used sparingly, in order that vomiting may be avoided, as this, with its convulsive movements, makes the withdrawal of the tube necessary even when the examination has been performed with the patient fasting. After cocaine has been applied to the larynx, the aspiration of vomited matter must especially be guarded against.

In all cases of bronchoscopic anæsthesia, the question of the preparatory administration of bromide or morphia injection must be considered from the previously established points of view. A patient should, if possible, only be examined fasting, and after he has been sufficiently prepared. All this has been fully dealt with in Chapter II.

POSITION.

As regards this matter, all that was said in connection with lower tracheo-bronchoscopy (p. 180) is generally applicable, but the greater difficulty in examining a patient lying down must be particularly insisted on. Beginners should never attempt this. While I have hardly ever known an examination to fail in my class (with a trained subject), even on the first attempt, when the patient was sitting, failure was almost the rule when he was lying down. I am therefore in the habit of preceding this method of examination by special preliminary exercises, of which I will speak farther on.

Bronchoscopy on patients lying down must of necessity be mastered, as in serious cases it cannot be avoided. It is not only that anæsthesia requires this position, but subjects are more easily handled, and interfere less with the operation, owing to the greater passiveness obtained when they are lying on their back. Whenever bronchoscopy is of long duration, the patient should be put in a lying position, both to avoid exhaustion and the aspiration of saliva. As the power of swallowing is nearly lost when the tube is introduced, and as, on the other hand, the tube seldom completely closes the larynx, the saliva collects and runs into the trachea and lower down into the delicate non-anæsthetized ramifications, and sets up constant coughing. For this reason alone the lying position is to be preferred when an operation is to last more than about ten minutes.

On the other hand, it has to be remembered that for many subjects, especially those who are elderly or corpulent, the horizontal position, with the head hanging over the end of the table, is of itself troublesome, and that they are better able when in a sitting position to cope with the increased strain on breathing. As the duration of examination must, in the case of such patients, always be limited as much as possible, the sitting position will be found most advantageous.

When upper bronchoscopy is applied with the subject sitting, a considerably lower chair must be used than is the case with the lower method. The best height is from 25 to 30 centimetres. The most suitable form of table has already been discussed in Chapter I.

2. Introduction of the Tube.

Upper tracheo-bronchoscopy may be regarded as a combination of the lower method and direct laryngoscopy. Both are connected with the passage of the larynx, and it is only in this part of the examination that there are any considerable differences of method. As it presents at the same time the most difficulties, it seems to me advisable to discuss here the different methods of introduction separately, except in the case of children as they require special consideration.

It has been stated before that with the long, narrow tubes which were used formerly the passage of the larynx was generally only effected by means of special instruments which might, as pilot bougies, serve for blind intubation, or, like Killian's divided spatula, render the autoscopic passage of the larynx possible. When my double tube is used these methods are unnecessary. The spatula-tube can always be introduced autoscopically without further expedients, and only those differences which arise from the various positions of the patient have to be considered.

All tracheo-bronchoscopic examinations, if scientifically carried out, begin with direct laryngoscopy, and may be divided into three stages, which the beginner is recommended to follow pedantically.

Stage I. Presentation of the lingual surface of the epiglottis.
Stage II. Passage beyond the epiglottis: autoscopic displacement.
Stage III. Passing the tube into the trachea.

INTRODUCTION WHEN THE PATIENT IS SITTING.

In this case the typical technique of autoscopy (Chapter III.), with all its details, must be applied, the short autoscopy spatula being replaced by the longer spatula-tube, the size of which will be determined according to directions already given. Usually no great difficulties of orientation arise in this respect with adults; but when the longer tube is being used, and the hand placed as mentioned on p. 101, great care must be taken to avoid lateral deviations and going too deep, as it is easy to pass across the epiglottis into the hypopharynx.

It is only necessary to present the entire glottis, as far as the neighbourhood of the anterior commissure, when a view of the trachea from the larynx is desired. Otherwise it is enough to present the last third of the vocal cords, as complete autoscopy requires a much stronger displacing pressure than is necessary for passing the tube. The sloping end of the tube presses the larynx backwards, in accordance with the counter-pressure procedure, so that when introduction is effected there is only a comparatively slight pressure of displacement. Patients who are difficult to examine may be afforded considerable relief by the employment of the counter-pressure method. Of course, the counter-pressor cannot be employed; but the action of this instrument may, to some extent, be obtained by manual displacement of the larynx. Unfortunately, the left hand will not be able to be used to protect the lips and teeth, and a particularly careful manipulation of the tube will consequently be necessary.

The passage of the larynx may be further facilitated by the following expedients: The subject should be asked to breathe calmly, slowly, and deeply, and the attitude thus assumed can be taken advantage of for passing the tube. It is not of much consequence whether complete abduction of the vocal cords is obtained, because the sloping end of the tube, if exactly in the middle line, can easily part them without causing much inconvenience. It is only when anæsthesia is incomplete that it may be necessary to insert the wedge-shaped end of the tube in a sagittal direction, in order to separate the apposed vocal cords.

When there is much resistance, the passage of the tube—after it has been well greased and warmed—may be facilitated by not pushing it with the right hand, but manipulating it with short leverage movements by means of the left index-finger. All friction against the teeth and the left hand is thus avoided, and the tube advances gradually without jerks.

INTRODUCTION WHEN THE PATIENT IS LYING DOWN.

Normally this is done with the patient lying on his back (Fig. 68), while an assistant supports his "hanging head" in such a way as entirely to relax the muscles of the neck.

In this, just as in autoscopy, too much strain at the outset must absolutely be avoided, and the surgeon should perform the first stage in a more or less upright position. The position of the electroscope follows from the general rule which requires the lamp to be directed sagittally to the patient. The left hand should then resume the position in which it protects the lips and teeth and insures the medial direction of the tube (see Fig. 28).

During Stage II. of autoscopic displacement, the patient's head must necessarily be lower (Fig. 68), so that the surgeon can resume a sitting position. Here again the protection of lips and teeth must be remembered, and no advance should be made in the manner indicated until the autoscopic presentation is obtained.

Introduction in the dorsal position is rendered difficult, not only because topographical relations are reversed, but because the electroscope has to be manipulated in an unaccustomed manner, and the direction of autoscopic pressure is inconvenient. It is therefore advisable, when there is an opportunity, to obtain some preliminary practice in autoscopy on sitting patients, the introduction being made by the surgeon standing behind the patient's back. The phonation (sound of breathing) must be attended to, and the three stages carefully observed.

When introduction in the dorsal position presents insuperable obstacles, it is usually possible to succeed in the following manner: Put the patient over on his left side, have the head supported, and then introduce exactly as in the sitting position (Fig. 72). When the tube is in the trachea, the patient should be carefully moved on to his back, because the lateral position becomes tiring for the surgeon. I have found that this introduction in a lateral position generally succeeds fairly easily even with inexperienced operators. The lateral position appears to offer no advantages for the further pursuit of the examination; in œsophagoscopy the opposite is the case, because the unaccustomed relative positions make orientation even more difficult. No doubt exceptions must occasionally be made—for instance, when there are objections to having the head hanging over the table (in the case of elderly people), or if it is desired to facilitate the removal of bronchiectatic secretion by raising the diseased side of the lungs.

In Fig. 73 is shown another position which I use occasionally. In it introduction succeeds with particular ease, as the patient is led to adopt a most favourable posture with his back

BRONCHOSCOPY, WITH THE PATIENT LYING DOWN.

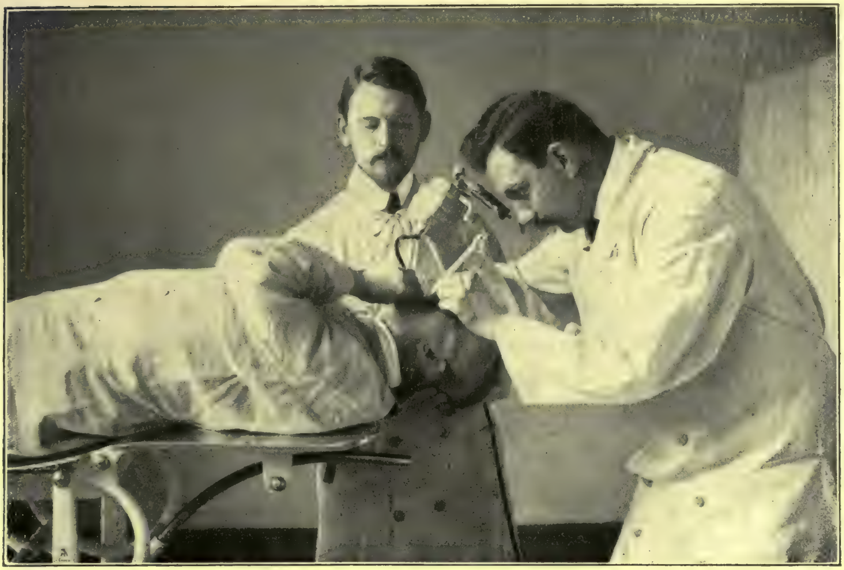

FIG. 68.—INTRODUCTION : STAGES I. AND II.

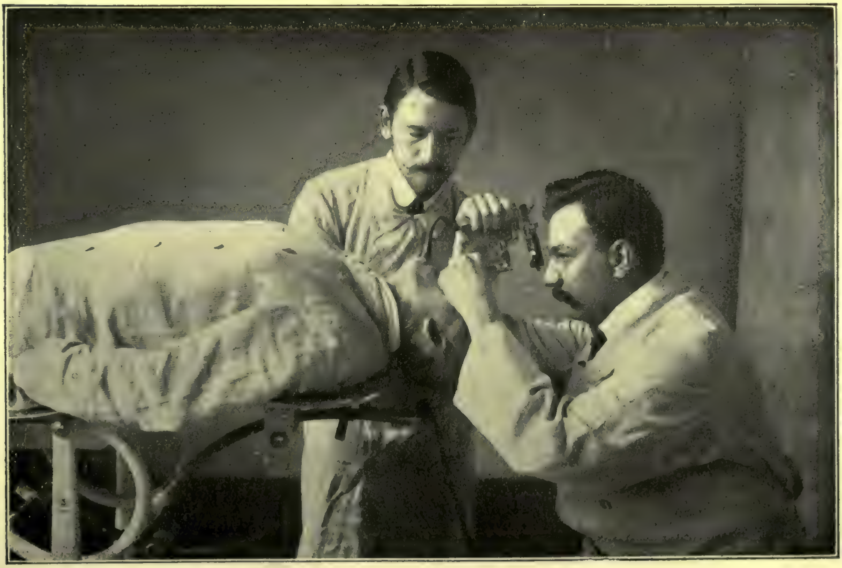

FIG. 69.—INTRODUCTION : STAGES III. AND IV.

BRONCHOSCOPY, WITH THE PATIENT LYING DOWN.

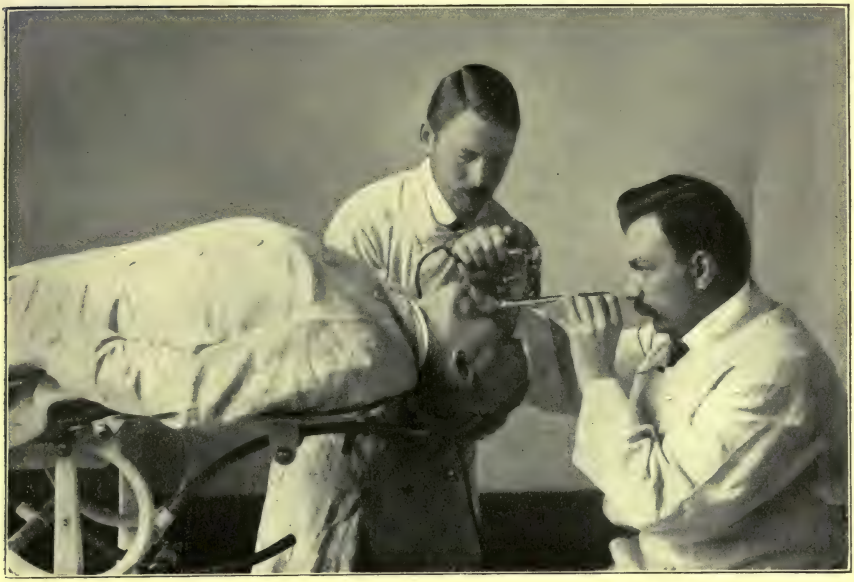

FIG. 70.—INTRODUCTION OF THE INNER TUBE.

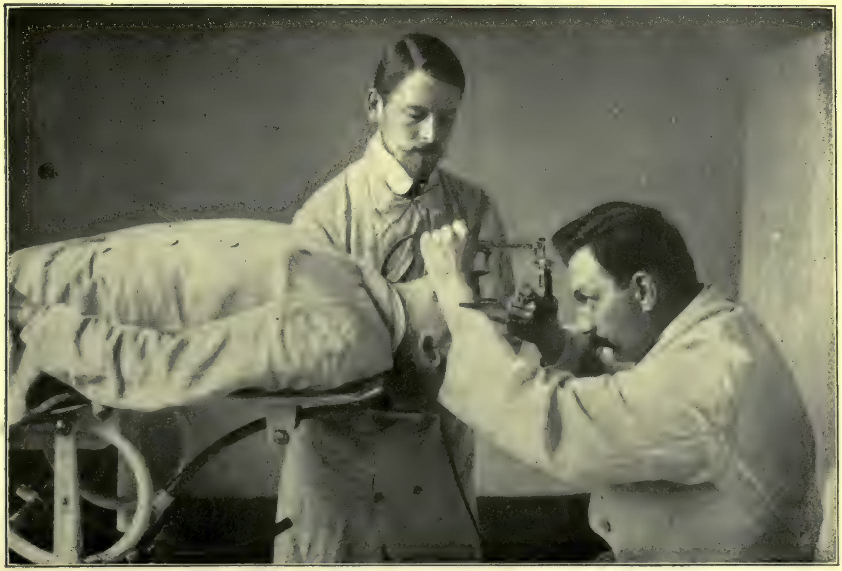

FIG. 71.—OPERATION WITH THE FORCEPS.

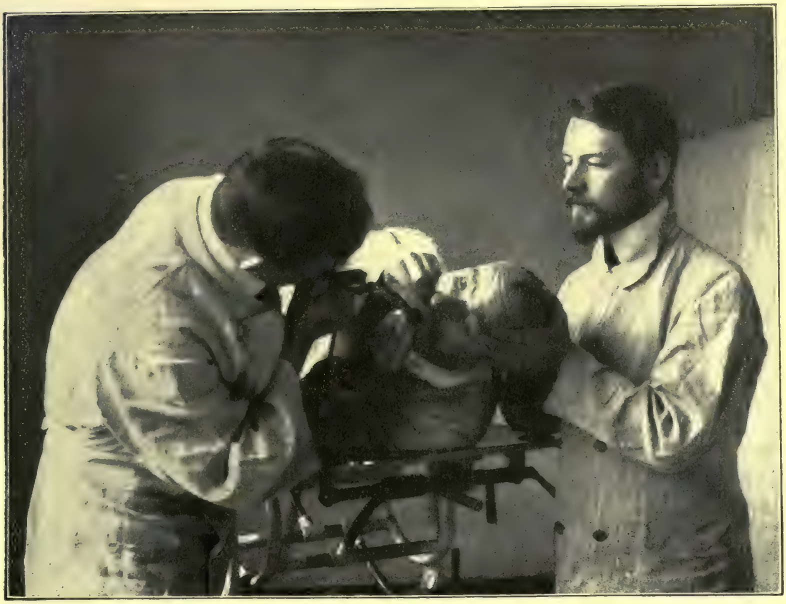

FIG. 72.—INTRODUCTION IN THE LATERAL POSITION.

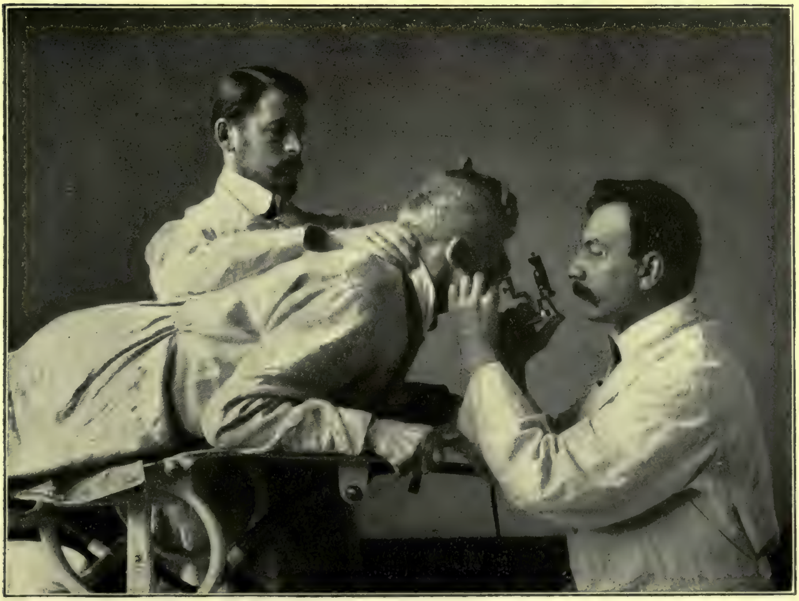

FIG. 73.—INTRODUCTION IN THE VENTRAL POSITION.

hollow. This position would be of practical importance in cases in which the sitting position is impracticable on account of disturbances due to saliva, while introduction in the dorsal position has failed, or in which that position, for some reason or other, cannot be borne.

3. Course of Examination.

As regards the general manipulation of the tube, when it has been introduced — tracheo - bronchoscopic presentation of the various wall and lumen images, orientation and limits of admissible endoscopy—reference may merely be made to what was said on the lower method, and consequently it is only necessary to say a few words on peculiarities connected with the upper method. These are chiefly connected with the employment of the extensible tube, and the measures involved in the more limited range of movement of the whole tube.

This limited mobility becomes already apparent in

TRACHEOSCOPY.

Immediately after the passage of the larynx, the posterior membranous tracheal wall is generally presented. This usually projects a little below the cricoid cartilage, and is apt, when the wall is presented, to convey the false impression of a stenosis or a retrotracheal tumour. An attempt should at once be made to obtain a presentation of the lumen by displacing the end of the tube forwards, and by lordosis of the subject's thoracic vertebral column. The latter is of the utmost importance, and, indeed, upper tracheo-bronchoscopy in general is distinguished from the lower method in that all presentations are effected, not only by the limited movements of the tube, but by simultaneous extensive "modelling" of the patient, so as to produce lordotic, kyphotic, and scoliotic curves of the cervical and thoracic vertebral column. The reason why operations are more easily carried out and are less troublesome to the subject in the sitting position is largely due to the greater mobility of these varying parts, and the greater advantage that can be taken of it.

In tracheoscopy, again, the rule holds that the examination should be made with the tube high and the lumen presented. When no important deviations are present, it should always be possible, by means of suitable positions to be discovered empirically, to obtain a view of the whole trachea as far as the bifurcation. The false position in Fig. 32 should be avoided. It is generally possible, by bending the head well over to the left side, to present the right main bronchus, especially if the tube is passed into the left corner of the mouth. In

BRONCHOSCOPY

this position in the corner of the mouth should be made the rule, even though there may be gaps in the front teeth, because the tube can then be held at a more oblique angle.

For the right main and stem bronchus, presentation with the tube high frequently suffices, and it is then not necessary to pass beyond, or even as far as, the bifurcation. I have extracted a foreign body from the right main bronchus through a spatula-tube, the end of which was between 3 to 4 centimetres from the bifurcation. If this indirect presentation of the main bronchi is not successful—and this is generally the case for the left side—it is best to introduce the extensible tube with the left hand, having the spring directed to the left and the lamp turned to the right (Fig. 70). It is advisable first to draw the tracheal tube back a little, in order that the inner tube may be at once completely introduced and the lamp pushed back again.

The tube is gradually advanced farther, the lumen being presented all the time with the left hand, while the spring is held held quite short. If any difficulties arise—for instance, if the lateral pressure hinders the advance in the left main bronchus—the tube spatula can be withdrawn a few centimetres over the inner tube, the fixing lever can be adjusted, and the two tubes then manipulated as if they were one solid tube. It should clearly be understood that this expedient should not lead to the employment of force, especially when the lumen is not seen. The fixing lever must only be used to retain the presentation of a field of operation.

It often happens that the beginner in advancing the inner tube draws back the tube spatula at the same time. The length of the tube projecting from the mouth should, therefore, always be looked to from time to time, and before fixing the lever the tube spatula should be pushed on as far as possible.

The presentation of the various bronchi is obtained on the same principles as with the lower method, regarding which pp. 185 to 190 should be reread. But it is considerably more difficult, and sometimes requires much displacement; and it is often necessary, while varying the position of the patient, to employ much force in affecting a lateral pressure against the bronchial walls. I have already said that the bifurcation in such cases may make excursions ranging up to 10 centimetres.

If, when the examination on one side has been finished, it is desired to pass into the main bronchus of the other side, the inner tube should be withdrawn as far as the bifurcation, the tube should be introduced into the other corner of the patient's mouth, and then advanced after the presentation has been obtained. Should the manipulation of the inner tube offer any difficulties, the change of side may also be effected by the corresponding displacement of the fixed double tube.

I have already observed that, whenever the spatula-tube of a given size of bronchoscope can pass the larynx, the inner tube may also be introduced into the main and stem bronchi, and from there the most important lateral bronchi may be brought into lumen presentation. If, as sometimes happens, direct entrance into these branches by way of upper bronchoscopy appears desirable, the inner tube may be replaced by one with a conically contracted end, such as I have had made for the two largest sizes of Fischer's bronchoscope. The entire tube is then 40 centimetres long. Orientation is naturally rendered more difficult, but it is much easier than it used to be with the earlier 40-centimetre tubes, because the field of illumination and operation maintains its full width up to the last 5 centimetres.

For the manipulation of the instruments the rules given for the lower method also apply, so long as account is taken of the directions given for longitudinal presentation. When the electroscope is used for operations with forceps, it is held in the left hand, with the lamp high (see Fig. 71), so that the free side of the tube opposite the spring is available for the forceps in the right hand.

A description of the special operative problems of bronchoscopy would lie outside the method of examination. I have already dealt with technical expedients, such as the choice of forceps end-pieces, the theory of stenosis treatment, and bronchial intubation.

When the bronchoscope is being withdrawn, first the inner tube and then the tube spatula is removed under the constant control of the eye. This procedure is especially to be recommended for the retrospective observation of discoveries already made.

Tracheo-bronchoscopy, when not prolonged, leaves no after-effects worth mentioning, so that in purely diagnostic cases it may be performed without the patient keeping his bed. The slight feeling of pressure in the larynx and the various degrees of hoarseness generally pass off on the following day, and require no particular attention. It is a different matter when the examination has been conducted in cases of stenosis, or if it is of considerable duration, and this is especially the case with children. In such cases it is necessary to keep constantly in view a possible increase of stenosis or subglottic swelling, which requires, therefore, not only constant watching but preparation in the event of tracheotomy being required. Ice bandages, breathing of oxygen, and possibly spraying of adrenalin, may often assist in tiding over the crisis. If tracheotomy is found to be unavoidable, even during examination, it may, especially when the patient is anæsthetized, be advantageously performed with the tracheal tube horizontal, because this keeps the breathing free and facilitates the quick finding of the trachea. Even when dyspnœa occurs suddenly after the tube is withdrawn, the momentary danger may be overcome by quickly reintroducing it.

It is scarcely necessary to discuss separately

MISTAKES AND DIFFICULTIES,

as these generally concern the presentation and passage of the larynx, and have accordingly already been fully treated in connection with the method of direct laryngoscopy.

The principal difficulty in upper bronchoscopy, as elsewhere, is due to the larynx being insufficiently treated with cocaine, and surgeons who are not well trained in laryngology must pay the greatest attention to this matter. When there is incessant straining, coughing, or choking, the introduction of the tube should, if possible, be delayed, and an endeavour made to prepare the subject systematically in the manner already described. If endoscopy has to be forced, the maximum dose of morphia should be given in the first place, and then a thinner tube may prove successful. In no case, however, should the experiment be carried so far as to render the patient unfit to stand even the lower method.

Even after the tube has been introduced, examination, orientation, etc., may be rendered almost impossible on account of constant coughing and expectoration. The expired breath, in the case of coughing, causes a pain in the cornea, so that protective glasses are sometimes indispensable. It is only through great perseverance that success can be obtained, and the degree of this not infrequently grows on each successive occasion. It should be a general rule for surgeons with little experience who are deficient in quickness and sureness, not to attempt to carry through everything at the first sitting in difficult cases.

4. Localization of Endoscopic Discoveries.

Under this head falls the consideration of problems of topical diagnosis on the one hand, such as not infrequently present themselves when the interpretation of complicated endoscopic discoveries is desired, and, on the other hand, the direct endoscopic support of external surgical operations in the region of the trachea and the bronchial tree or the lungs. I wish to add here two auxiliary methods, which I shall briefly describe as "tracheography" and "bronchometry."

TRACHEOGRAPHY.

Endoscopic discoveries in the trachea, such as compressions, deviations, fixations, tumours, etc., not infrequently require for their interpretation and operative treatment an exact projection on the surface of the body, with indications of their position in relation to fixed points of the thoracic skeleton. In the case of stenoses, such as are sometimes caused by struma, the surgeon may find it useful to get an exact indication of their length, the relative intervals between several constrictions and their relation to the aperture of the thorax.

It was hitherto difficult to obtain such indications, because skiagrams only show the lateral compression and deviation of all tracheal changes, and are apt to fail entirely in the region of the mediastinal shadow. On the other hand, tracheoscopic valuation with one eye is subject to very great errors, and the external application of measured distances is rendered abortive by the projecting chin and the varying distances between the trachea and the surface of the body. The same applies to the numbering of the tracheal rings, which only afford the means of calculating absolute longitudinal measurements when both their varying total number and the entire length of the trachea and the position of its upper end are known. I have therefore had a simple device prepared, which, in connection with the electroscope, allows the situation of the endotracheal discoveries to be registered perpendicularly on the surface of the body. The instrument, which I call a "tracheograph" (Fig. 74), consists of a framework of steel wire shaped like a ladder, which is fastened to the handle of the electroscope by means of two points (for this purpose two small holes must be bored into the end of the handle). A pencil for the skin is fixed to the framework, so that it can move up and down, and, by simply turning it, can be held in any position.

The tracheograph is used in such a manner that the pencil is set, before introduction, so that its point coincides with the end of the tube spatula used in examination, both longitudinally and transversely (lateral deviation may, if necessary, be corrected by a corresponding bend of the top of the framework). While tracheoscopy is being performed, the pencil is pressed against the skin, and can, if necessary, be pushed into its case until the framework comes into line with the prolongation of the electro-

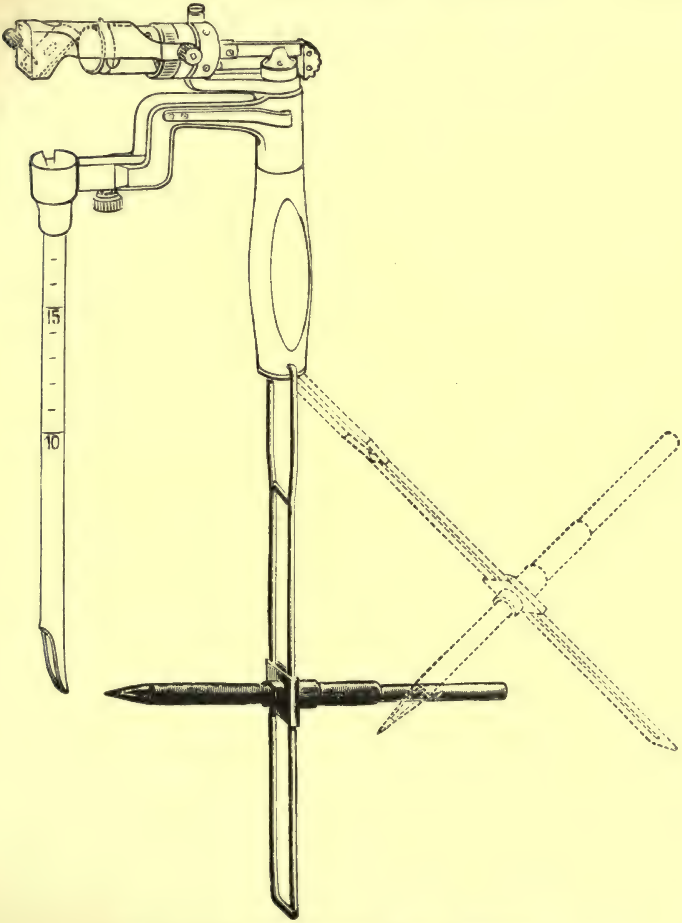

FIG. 74.—TRACHEOGRAPH. (After Brünings.)

scope handle (Fig. 75). In this case it is also possible, by dividing the pencil accordingly or by subsequent measurement, to ascertain the perpendicular distance of the tracheal discoveries from the surface of the body in centimetres.

In Figs. 78 and 79 I have represented photographically two such tracheograms (with the appropriate additions that are required). It is clear that not only the situation and length of stenosis, but also the direction of lateral deviations, can be represented. No doubt the tube must then be so manipulated as to allow of its end following the outline without lateral displacement. In the first case (Fig. 78) the tumours corresponding to the tracheal compressions were also ascertained orthodiagraphically. The orthodiagram (Fig. 77), taken with the patient in a sitting position, corresponds pretty exactly with what was found tracheographically.

An extension of the tracheographical principle to the bronchus is, of course, rendered impossible, because the introduction of the tube changes its normal position. Moreover, when topographic measurements of the bronchial tree are being taken, the part to be discovered from outside has to be determined in three dimensions. Such a method of measurement I will briefly describe as

BRONCHOMETRY,

which has already been attempted several times. For the skiagraphic localization alone, according to Hildebrandt's table, about seventy different methods have been mentioned, some of them very complicated. In the bronchial tree, moreover, it is often necessary to mark the point to be determined by introducing a foreign body, which can be shown skiagraphically. Even this procedure offers great practical difficulties, for a rigid sound will cause displacements, whereas with a flexible or mobile one it is scarcely possible to attain a reliable fixation.

It also happens that the most exact topographical determination is no guarantee of discovery when pneumotomy is undertaken—for this reason alone, that in transpleural pneumotomy displacements can occur. How uncertain the operative discoveries of

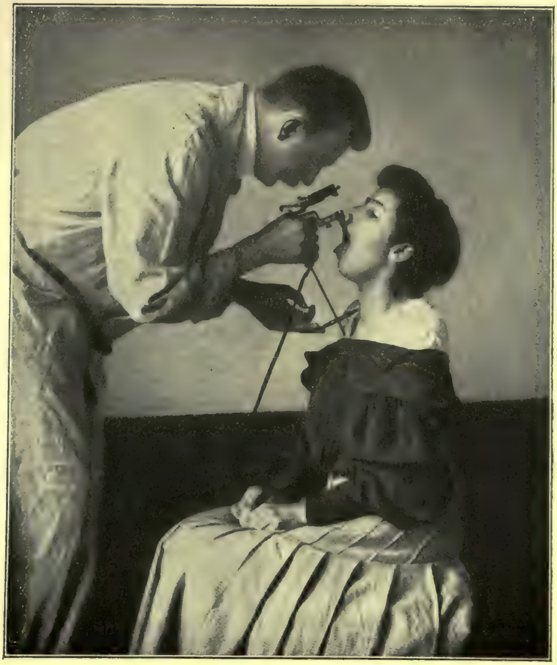

FIG. 75.—TRACHEOGRAPHY.

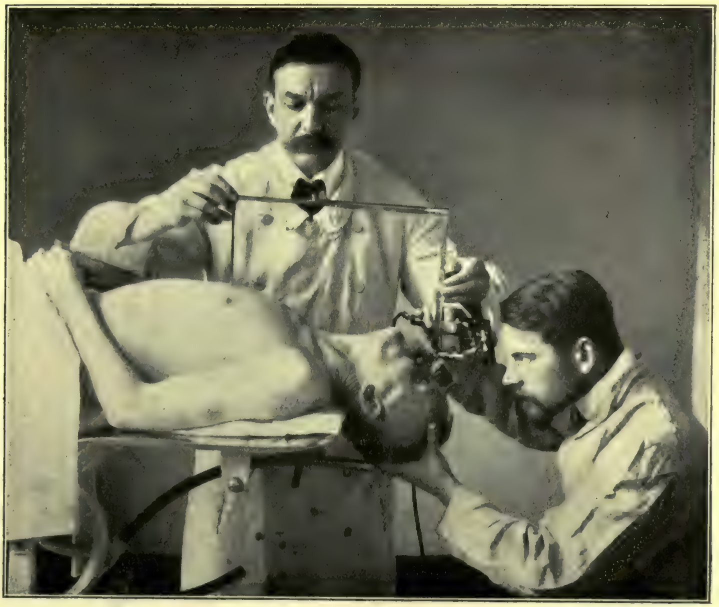

FIG. 76.—BRONCHOMETRY.

PLATE XXI.

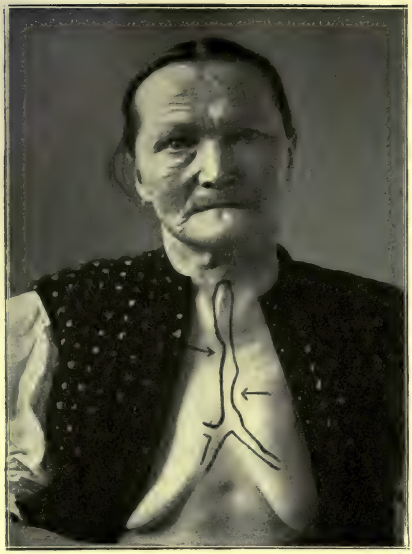

FIG. 77.—TRACHEOGRAM IN A CASE OF DOUBLE COMPRESSION STENOSIS.

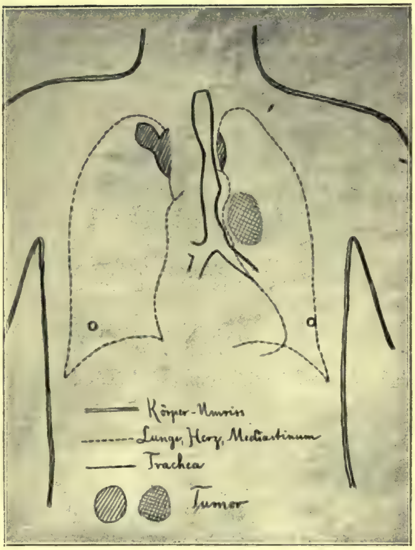

FIG. 78.—ORTHODIAGRAM OF THE SAME CASE.

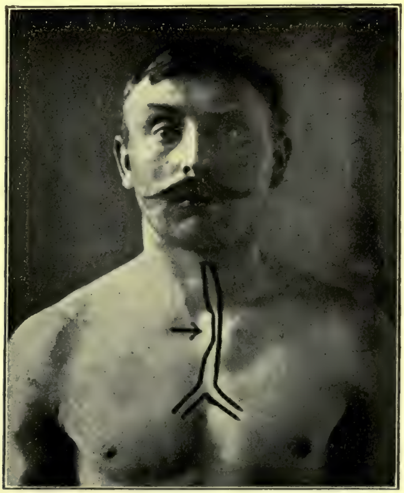

FIG. 79.—TRACHEOGRAM IN CASE OF ENDOTHORACIC COMPRESSION, WITH DEVIATION OF THE TRACHEA.

To face page 208.

pulmonary foreign bodies are appears from Tuffier's and Karewsky's* statements, to the effect that, in twenty-five cases where pneumotomy was performed, the foreign body was only found in three instances.

Another way has been tried by Hoffmeier, in the case communicated by Schefold†—viz., the introduction, by palpation, of rigid sounds or tubes, which the operator can feel after the pleura has been opened. In this case the lung tissue was forcibly pierced by the tube which was introduced, until the operator could reach the end of the tube, the presence of which could be felt from the surface of the lungs. Killian‡ has fully discussed the employment, by palpation, of sounds introduced bronchoscopically, and has pointed out their occasional value in surgical operations on the lungs. Unfortunately, as in Hoffmeister's case, feeling through with the sound in cases where the lung is consolidated or infiltrated cannot be relied upon when the distance is great, apart from the difficulty of maintaining the guiding instrument in the desired direction when it is far down and when irritability is considerable.

I have therefore attempted to insure the finding of bronchial spots, endoscopically presentable, in transpleural pneumotomy, either with the knife or the Pacquelin cautery, by using a sort of jointed compass. The instrument (Fig. 80) may be attached to any bronchoscopic tube, and, by modifying the lengths of the vertical or horizontal shanks, can easily be so placed that its blunt end always points directly to the end of the tube. When applied, the point of the compass either directs the knife or it is itself fitted with the Pacquelin cautery. The surgeon is, moreover, in a position, by means of lung compression on each side, to move the presented bronchial part nearer the surface. During the operation he is kept constantly informed, by the centimetre scale of the extensible vertical compass shank, with regard to the depth of the point of operation or its distance from the end of the tube.

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* Quoted from H. von Schrötter, *loc. cit.*

† *Beitr. z. Klin. Chirurgie*, Bd. 43, Heft 3.

‡ Chirurgen-Kongress, 1905.

No opportunity has yet presented itself for using this "bronchometer," so that I cannot enter into a discussion of its practical value. By means of this method it is probably possible only to deal satisfactorily and in the quickest manner with cases where the bronchi have at least a lumen of 5 millimetres, from which, if need be, the further advance would have to be peripheral. The form of bronchometer shown in the figure, moreover, only allows of a more or less ventral entrance, but the instrument might easily, especially in the case of the lower tracheobronchoscopy, be so modified as to allow of lateral pneumotomy

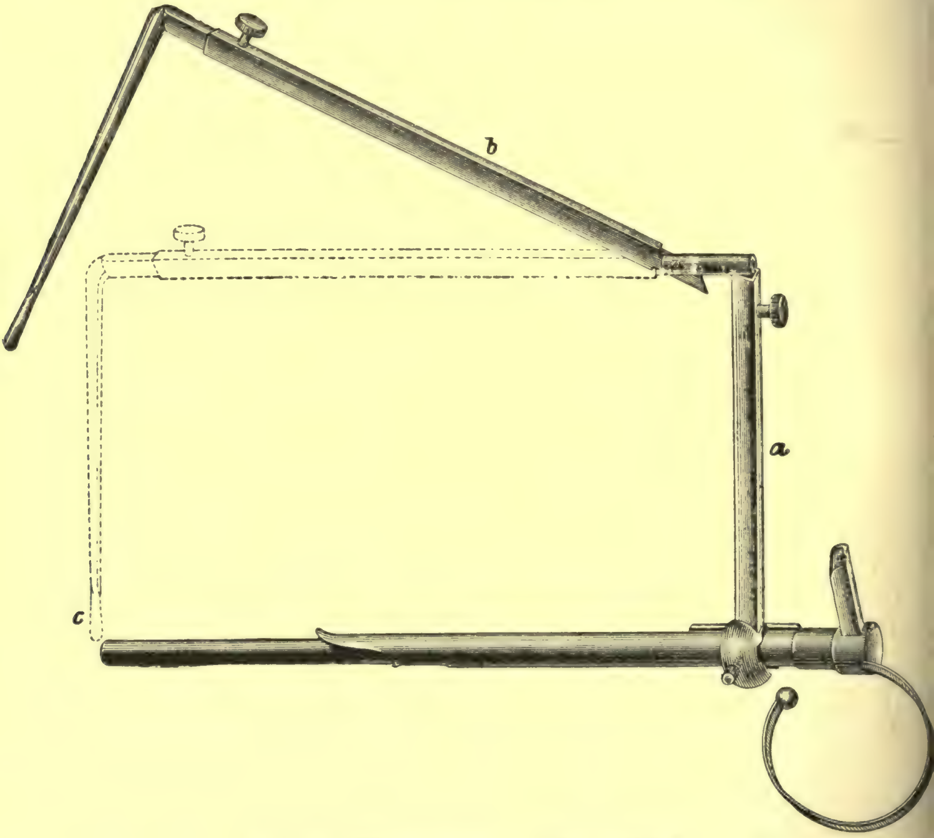

FIG. 80.—BRONCHOMETER. (After Brünings.)

being applied. As far as the operative removal of foreign bodies is concerned, it often happens that there is also a tracheotomy wound. In such a case the bronchometer may be made in a very simple and handy form, but I will defer the description of it until an opportunity occurs for its employment.

I believe that I am justified in recommending the bronchometric method, while at the same time pointing out the difficulties connected with its application, and indicating the limits of its efficiency. Pulmonary surgery altogether includes many problematical points, and it has hitherto profited so little from bronchoscopy that it is very proper to encourage efforts in this direction.

CHAPTER VI

DIRECT EXAMINATION IN CHILDREN

I. IMPORTANCE OF ENDOSCOPY IN CHILDREN.

WHEN I mentioned the use of direct laryngoscopy and tracheobronchoscopy in the case of small children (Chapters III. and V.), I did not lay any special stress on it, as I wished to detail the normal procedure as clearly and comprehensively as possible. On account of the unusual difficulties encountered in the direct examination of children, it is not only necessary to employ numerous variations of method, but additional instruments are also very useful in certain cases. If, then, the undoubted importance that the method must assume in the hands of children's specialists is considered, no further excuse for the inclusion of this chapter is necessary.

The difficulties in examining children lie, in the first place, in the relative smallness of the parts to which the endoscopic apparatus must be adapted. The diameter of the bronchoscopic tube is reduced to 7·6 millimetres, and approaches the limit at which orientation or the manipulation of instruments under the guidance of the eye is possible.

In addition to this the restlessness of children, their tendency to spasm and salivation, the forcible respiratory movements of the trachea and bronchi, and, above all, the increased danger of collapse owing to the use of cocaine or a general anæsthetic, must be taken into account.

The endoscopic treatment of children yields, however, such gratifying results that it surpasses in importance the endoscopy of adults. In this connection I need only mention the case of foreign bodies, of which far more than half occur in childhood. According to the statistics of Gottstein, which I have already referred to frequently, the series of 111 cases of foreign bodies which he treated bronchoscopically show the following age distribution:

Age (years) -	0–1	1–2	2–6	6–12	12–18	18–63
Foreign bodies	6	11	35	17	6	36

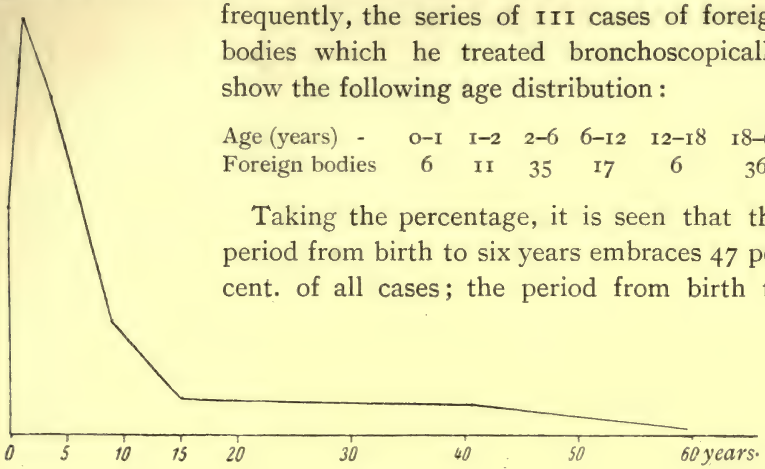

FIG. 81.

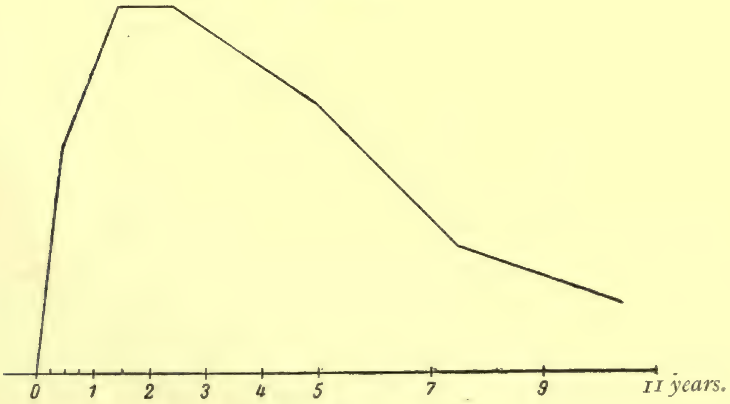

FIG. 82.

Taking the percentage, it is seen that the period from birth to six years embraces 47 per cent. of all cases; the period from birth to twelve years old, 69 per cent.; whilst the entire period from twelve to sixty-three is only responsible for 38 per cent.

It is particularly instructive to set out this distribution graphically as is done in Figs. 81 and 82.

The upper curve gives a general review of the frequency of foreign bodies during the whole period from birth to sixty years. It shows the enormous rise in frequency which occurs soon after birth, and the marked decline about the age of fifteen, after which the diminution progresses gradually.

In the lower curve I have accurately depicted the interesting period from birth to ten years. It can be seen from it that the highest point occurs about the second year, after which there is a fairly straight progressive fall until the age of ten.

The ordinates are based on the average statistics, and the equidistant abscissæ represent the age in years. If the distance of the various points on the circumference of the curve is measured, the number of foreign bodies in a given period of time is obtained.

The curve also shows that more than half the foreign bodies are swallowed before the age of eight years. This synopsis is sufficient to show the importance of the direct examination in children, so that I need scarcely mention its importance in the diagnosis and treatment of difficult decanulation in the endoscopic treatment of diphtheria, etc. It should further be remembered that autoscopy is practically the only possible method for diagnosing and treating affections of the larynx in children.

II. INSTRUMENTS.

The instruments contained in any normal set usually suffice for small children, but it is obvious that an instrument which is strong and big enough for the examination of grown men is not exactly the one most suitable for small children. I will therefore describe some special instruments and their degree of importance as well as the special advantages attaching to their use.

For general use, the composition of a set suitable to children's requirements will be given, and the children's specialist can confine himself to these.

Electroscope.

In the mechanical construction of my "broncho-electroscope," the application of force which the autoscopic displacement in

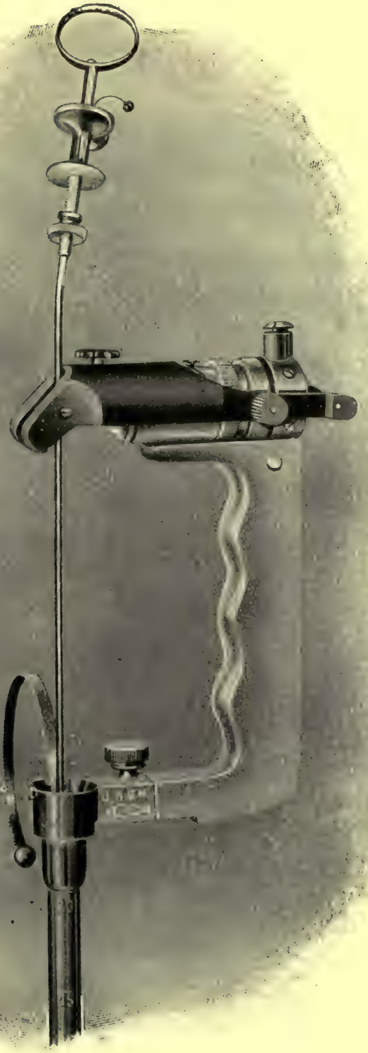

FIG. 83.—UNIVERSAL ELECTROSCOPE. (After Brünings)

adults entails must be taken into account. The special handle which I constructed with this object is neither necessary nor, in many cases, convenient for the examination of children. For lower tracheoscopy, which is so much more frequent in children, the handle is inconvenient, owing to its length and weight being relatively so much greater than that of the small tracheal funnel. The mechanism, also, whereby the lamp can be pushed to one side is not of much use in children, as their delicate air-passages do not permit of the lateral pressure bound up with this manœuvre. I would advise, if the equipment is very complete, that the "Universal Electroscope" (Fig. 83) should be used for children.

The instrument was devised to meet the surgeon's requirements in all classes of endoscopy (air-passages, œsophagus, rectum, urethra, etc.), and it is particularly suited for the examination of children.

The lamp and projection apparatus are the same as in my broncho-electroscope, but the light handle affords more easy manipulation in those cases where the employment of force is not necessary, and where the tube must lie close to the surface of the body (tracheal fistula, etc.). The mechanism of the mirror-holder is also very convenient in examining children. By pressure of the thumb it is clipped into position above the upper end of the tube, and when the pressure is removed it flies back into its original position. I have often used the instrument to great advantage in lower tracheo-bronchoscopy.

Tubes.

A special spatula is particularly desirable in direct laryngoscopy of children, and I have devised one to meet the case (Fig. 85). The instrument is grooved and has a somewhat broad fish-tail end, the upper half is bent round to form a kind of box, which is, however, open on the right side, so as to facilitate the introduction of instruments and their manipulation at an angle. I must further recommend the use of the five normal bronchoscopic tubes through a tube, No. 1½, of 7·75 millimetres diameter, which is more suited to children's requirements, and is midway between No. 1 (7 millimetres) and No. 2 (8·5 millimetres). It is made of tempered steel.

Exact observation in the neighbourhood of a tracheotomy wound (difficult decanulation) makes necessary the use of a special "tracheal funnel," such as I have figured in Fig. 86. The sloping end serves for the earlier use with a mandrin, and allows a complete inspection of the whole length of the wound. The tracheal funnel is manufactured in three sizes—5, 6½, and 8 millimetres in diameter. The longest size does very well for direct laryngoscopy of infants.

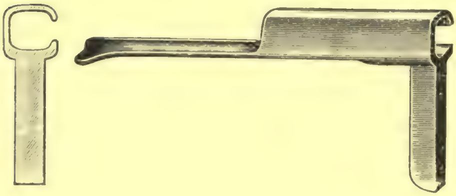

FIG. 85.—AUTOSCOPY SPATULA FOR CHILDREN. (After Brünings.)

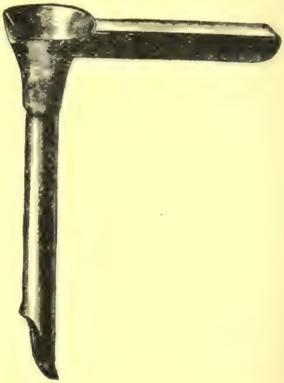

FIG. 86.—TRACHEAL FUNNEL. (After Brünings.)

Instruments for Operations.

The extreme narrowness of the tubes for children makes operating "under complete ocular control" largely an illusion. I have, however, had a forceps 17 centimetres long constructed, which can be held and manipuluted very delicately owing to its shortness and absence of any lengthening mechanism. Its small end-pieces are interchangeable. The instrument is very useful for the extraction of difficult foreign bodies, and I have also used it for the removal of diphtheritic membrane from the bronchi. It is further advisable to have an extra thin pump-tube and wool-carrier.

III. DIRECT LARYNGOSCOPY.

Anæsthesia.

Wherever painting under guidance of a mirror is possible in older children, the method described for adults should be adopted, but the cocaine solution should never be stronger than 10 per cent. A short, bent steel wool-carrier or a nasal probe is more convenient than the painting syringe.

For small children reliance must be placed on cocainization by palpation, as a spray is out of the question. It usually suffices to bring the epiglottis into view with a tongue spatula—though this is often not possible—and to paint its laryngeal surface with a curved wool-carrier more or less under visual control. As a rule, however, the finger must be passed into the larynx, and, guided by that, the painting done as well as possible.

In infants anæsthesia must be dispensed with. In inducing anæsthesia, the great tendency that small children have to subglottic swelling should always be remembered, and the painting should therefore be proceeded with very cautiously. If any laryngeal dyspnœa is present, any painting is contra-indicated. In laryngeal affections of unknown nature, it is advisable to make the examination without anæsthesia—as can often be done—or to use a general anæsthetic.

General Anæsthesia should be used for prolonged or especially difficult examinations, and should be limited to those conditions in which absolute stillness is essential. It is obvious that general anæsthesia is more often necessary in bigger children, as they cannot be expected to keep still spontaneously, and any compulsion is merely a prelude to further difficulties. However, at this age indirect laryngoscopy is often practicable.

Position.

The sitting or upright position is a great help in examining children. The child should be held almost in the position usual for adenoid operations, but need not be so completely wrapped up in a blanket. The head must, however, be able to be moved passively, so that a second assistant is almost indispensable. For prolonged anæsthesia the lying position is indispensable, but a short anæsthetic may be administered without danger while the child is sitting up. The lying position further facilitates the fixation necessary for accurate examinations or operations under local anæsthesia, and diminishes disturbances caused by the profuse salivation.

A somewhat higher table is necessary for examinations in this position, and the top should be covered with a light cloth to aid in keeping the patient firm.

Examination.

The method which has already been described will serve for direct laryngoscopy both in the sitting and lying positions, but it must be borne in mind that unless a general anæsthetic is used some degree of compulsion will be necessary in making the examination. Not only is no help obtainable from the patient, such as the assumption of a suitable position, light breathing, holding of the tongue, phonation, etc., but every device has to be used to overcome active opposition.

The child jerks its head, bites the spatula, and moves the base of the tongue in all directions, so that a typical observation of the third movement can never be relied upon.

In addition to this must be considered the hopeless tendency that the pharynx, pars supraglottica laryngis, and the glottis, show towards sphincter-like closure, and that even in the momentary intervals of relaxation the opening is usually hidden by a foaming mass of pent-up secretion ; whilst a recollection of the delicacy and the diminutive size of the parts, and the ever-present necessity for the utmost caution, often discounted, however, by sudden movements, will give some idea of the difficulties involved in the examination of children.

Fortunately, however, there are gleams of sunshine even in this difficult task. Children are as a rule very suitable for autoscopy, not only on account of the plasticity of the soft parts and the easy mobility of the vertebral column, but also, as Wild* pointed out, on account of the transition from the pars laryngea pharyngis to the axis of the bronchi being straighter than in the adult. A relatively wider tube spatula can therefore be used, or, better still, my grooved children's spatula with open-sided box (Fig. 85). Orientation is facilitated with this latter instrument, so that full electroscopic illumination is obtained, and the first and second movements can be readily carried out and a large field of vision secured. The spatula should not be held too obliquely, and the difficulty of keeping the mid-line on account of the mobility of the tongue should be minimized by using the handle previously described.

A further manœuvre consists in waiting, and using the brief moment of inspiration for the introduction, and in allowing an assistant to pump away the accumulated saliva as rapidly as possible.

The "suction spatula," which I formerly used, did not come up to expectations, for as in the case of other similar instruments, the saliva was only removed from the immediate neighbourhood of the suction holes; it is better simply to put the pumping-tube into the throat. The use of a gag is often advantageous.

Children's necks are very easily moved, and great care must be taken that the head is not unduly extended.

The maintenance of the larynx presentation, when once it has been attained, is usually easy, but the view is apt to be limited to the short period of inspiration.

Whether counter-pressure autoscopy may be an advantage in children is as yet unproved. The procedure would scarcely diminish the autoscopic pressure, as this is in any case very moderate.

IV. DIRECT TRACHEO-BRONCHOSCOPY.

Lower Method.

There are no material differences from the procedure as carried out on adults. It is, however, very important in children with permanent tracheotomy-tubes to use the short tracheal funnel described above, as this facilitates the accurate examination and treatment of the trachea in the neighbourhood of the wound, and is especially useful in the region of the subglottic space.

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* "Uber topogr. Altersveränderungen des Atmungsapparates." Jena, 1901. (zit n. Wild).

In examining the air-passages the powerful movements of the lumen during respiration are very striking. Occasional forced expirations often bring about complete obliteration of the lumen accompanied by a cough-like stridor. In the region of the smaller bronchi the movements of the lumen are very troublesome, as, owing to the swelling of the mucosa, the chance of satisfactory orientation is often dependent on a fleeting sight of the lumen obtained at the moment of inspiration. I have often noticed this in cases of diphtheria.

Every advance should be made cautiously, and where the presence of a foreign body is suspected, the result of the examination should not be deemed satisfactory until every branch on both sides has been presented, into which the foreign body might have been sucked.

Upper Method.

The upper tracheo-bronchoscopy of small children is one of the most difficult endoscopic procedures, and when the difficulties appear insuperable, beginners would be well advised to perform immediate tracheotomy, rather than exhaust the patient by fruitless attempts at introduction.

If it is thought advisable to conduct the examination under local anæsthesia, the technique of cocainization described for direct laryngoscopy should be followed, and the air-passages can be cocainized through the tube after the larynx has been passed.

The indications for general anæsthesia have already been mentioned in Chapter II. To the special technique there mentioned should be added the recommendation that the autoscopic cocainization of the larynx should not be undertaken until anæsthesia is fairly deep, as the initial increase of reflex and the corresponding increase of salivation render the presentation of the larynx more difficult. It is helpful to pull the tongue out a little to limit its movements, whilst the use of a gag is often an advantage.

The introduction of the tube calls for special mention, as departures from the technique normally applicable to adults are often inevitable.

I shall put the normal procedure in the first place, the autoscopic introduction with the aid of a spatula in the second place, and the blind introduction with a mandrin in the third place.

I will discuss the various procedures in this order, and will then consider their advantages and disadvantages.

1. The direct autoscopic introduction of the tube spatula is naturally more difficult, owing to the diminished field of vision in children, than is ordinary autoscopy with a broad spatula. If the difficulties appear insuperable in the lying position, an attempt should be made in the sitting position, as I consider that this position is permissible, for a short time, even under a general anæsthetic. If this fails, introduction in the left lateral position may be successful.

2. For autoscopic introduction with the aid of a spatula, an attempt should be made to present the larynx with the autoscopy spatula; this is then directed somewhat obliquely, and the tube spatula introduced by its side and pushed through the glottis. The electroscope is then removed from the autoscopy spatula and fitted to the tube which has been introduced.

Before the introduction, the light of the electroscope must be centred for the tube that is to be introduced, and should not be interfered with again.

3. Some authors prefer to introduce the tube blindly under guidance of the fingers. To do this, a good elastic catheter should be used as a mandrin. This should project from 3 to 4 centimetres beyond the end of the tube, and should be bent with the finger so that it finds its way over the epiglottis. When withdrawing the mandrin, care must be taken that the tube is deep enough in the trachea; otherwise the tube may slip out as well.

This enumeration shows that a number of methods of introduction are available, and they can all be employed in the different positions of the body.

An estimation of their relative practical worth is difficult to come by, as personal predilection—experience of intubation or familiarity with endoscopic routine—plays so large a part.

Blind intubation is a comparatively easy procedure, though personally I have not much experience of it, but it is not in keeping with the fundamental endoscopic rule that the eye should guide the hand. I only advise its adoption by those accustomed to it in cases of extreme urgency, such as sudden dyspnœa, and even in them I would urge the practice of autoscopy, as it is so indispensable on other grounds.

Of the autoscopic methods, I would suggest that the beginner employs the direct introduction in the sitting position, especially as this may be done under general anæsthesia if the manipulation is fairly rapid.

After some practice in this procedure, a trial can be made of the somewhat analogous procedure of introduction in the left lateral position.

The localization of the delicate epiglottis is often difficult in children, owing to their restlessness and profuse secretion of saliva.

Under no circumstances should the details of the first movement be slurred over, but the root of the tongue should be carefully defined, so that, when the tube spatula is held obliquely, it is possible to see along the side of it, the instrument thus serving for illumination and as a tongue spatula. If this manœuvre fails, recourse must be had to the procedure detailed under heading 2, with the autoscopic use of the flat box spatula.

Good anæsthesia and complete fixation are indispensable for the last method, as both hands are occupied. It should always be a rule never to undertake difficult bronchoscopy in small children without proper preparations for assistance as regards fixation, anæsthesia, and possible tracheotomy.

The rules framed for adults must be accurately followed in performing bronchoscopy. It has already been mentioned that the larynx of a child, which is very narrow in proportion to its trachea, allows the use of relatively wider tubes on account of its plasticity.

The mobility of the tube is a great advantage, but nevertheless orientation is always difficult, on account of the limited field of vision and the strong respiratory movements. A powerful light, clean inner tube, and the use of children's forceps and pumping-tube, render operative procedures easier.

In conclusion I would lay stress on the dangers of a too prolonged bronchoscopy in children, on the absolute necessity of an exact observation of the general condition, and on the possibility of subsequent subglottic swelling. The value of oxygen inhalation in this last condition is very great.

CHAPTER VII

ŒSOPHAGOSCOPY

HISTORICAL SURVEY.

I PREFACE this chapter with an historical introduction, chiefly because the history of œsophagoscopy is of special interest to my colleagues. It shows that the first successful attempts to obtain œsophagoscopic images were carried out by laryngologists, and that, accordingly, the connection of the œsophagus with their special study is confirmed on historical grounds,* though this is far from being generally conceded in spite of the close connection between the air and food passages and of the similarity of the tracheo-bronchoscopic methods.

A few years after the invention of the laryngoscope attempts were made by laryngologists to extend the mirror method, which was so successful, to the adjacent organ—the œsophagus. The technical problem in these attempts was, in the first place, by means of suitable specula, to obtain a view of the cervical portion of the œsophagus. As far back as the sixties, Semeleder and Störk carried out such experiments with a speculum but did not obtain any practical results. The same was the case with Bevan in 1868, who used a skeleton speculum, but it was not until two years later that Waldenburg succeeded for the first time in introducing a short tubular mirror, 14 centimetres long, into the mouth of the œsophagus and so was able to make an ocular diagnosis of a diverticulum.

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* A complete historical account, from which, indeed, most of the following data are taken, may be found in Störk, *Oesophagoscopie*, Würzburg, 1905; also Gottstein, "Technik u. Klinik der Oesophagoscopie," *Mitteil. a. d. Grenzgeb. d. Mediz. u. Chirurg.*, Bd. 6 u. 8, 1901; Killian, "Zur Gesch. d. Oesophago- u. Gastroskopie," *Deutsche Zeitschr. f. Chirurg.*, Bd. 58, 1901.

Immediately after this, Störk resumed his œsophagoscopic experiments, adding to Waldenburg's instrument a lobster-tail articulation in order to facilitate introduction. But when it became necessary to reach lower down with a longer speculum this principle could no longer be technically carried out. Thus Störk was forced to make use of a long rigid tube, and with it succeeded in realizing direct œsophagoscopy for the first time. Whereas all previous specula terminated in the pharynx, illumination and inspection being effected indirectly by the laryngoscope, Störk's long tube protruded out of the corner of the mouth during inspection, the cervical column being extended. Thus he replaced the laryngoscopic procedure by direct illumination and inspection. The indirect method with the speculum was, however, by no means finally abandoned. As late as the eighties Mackenzie, and after him Lowe, tried to obtain a view of the upper part of the œsophagus by means of a skeleton œsophagoscope which ended in the pharynx and was used with the laryngoscope, but they did not obtain results of general importance. The Leiter-Nietze œsophagoscope, which was furnished with an internal lamp and a system of prisms like a cystoscope, followed the indirect principle. I may also mention recent attempts to dilate the uppermost part of the œsophagus sufficiently for an examination with the mirror to be possible. Of these indirect methods, only that of von Eicken (hypopharyngoscopy), which will be referred to later, has practical significance.

Although the work so far mentioned represents development in a continuous direction judged from a laryngoscopic standpoint, reference must be made to the somewhat different experiments of an investigator who applied to œsophagoscopy the technique which he had evolved for the examination of the stomach. As far back as 1868 Kussmaul made a report to the Scientific Society of Freiburg on successful examinations both of the normal and morbidly affected œsophagus, in which he employed direct inspection by means of rigid tubes of the same thickness and length as are still employed, using Desormeaux's apparatus for illumination. These experiments were continued by his pupil Müller, and yielded the important practical result that a rigid tube 13 millimetres in thickness may be introduced into the œsophagus of "all normally constituted persons."

The decisive experiments of Kussmaul with the œsophagoscope were only rescued from oblivion by Killian.* Unfortunately, Kussmaul did not publish anything to make his method known, and consequently his system found no imitators, at least in Germany, and was not perfected. It is not therefore possible to give Kussmaul the credit of establishing œsophagoscopy as a clinical method.

As Störk also neglected to chronicle his exceedingly numerous and valuable œsophagoscopic observations and his extraction of foreign bodies, the credit of the method belongs almost entirely to von Miculicz. It appears that Leiter senior, that gifted Viennese inventor of instruments whose name is inseparably connected with the history of endoscopy, induced von Miculicz to take up œsophagoscopic experiments, without, however, informing him of Kussmaul's experiments with which he himself was quite familiar. Consequently, modern œsophagoscopic technology, founded by von Miculicz, does not reach back to Kussmaul but to Störk, whose successful introduction of straight tubes was familiar to him from personal observation even at the commencement of his labours. Von Miculicz combined these straight tubes with Leiter's illuminating apparatus—*i.e.*, an "interior lamp" of platinum wire with water cooling—and thus obtained the first generally applicable œsophagoscope, by the aid of which even in 1881 he was enabled to carry out the most important anatomical, physiological, and pathological investigations of the œsophagus. These labours followed each other in swift succession, and are so complete that they form in all essential points the basis of what is known to-day.

The modern history of œsophagoscopy since the researches of von Miculicz ten years previously only made a fresh advance towards the end of the last century. This was chiefly due to the complicated and unreliable illumination with platinum wire standing in the way of its general practical adoption. The advance has occurred in two directions—viz., popularization and general acceptance of the method, and improvements in the details of technique. In the former direction it is chiefly von Hacker, and after him Rosenheim, Gottstein, and Starck, whose efforts have been attended with success; whilst Kirstein, and more especially Killian, have by their publications and demonstrations awakened or reawakened the interest of laryngologists in this method.

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* "Zur Geschichte der Oesophago- und Gastroskopie," *Deutsche Zeitschr. f. Chirurg.*, Bd. 58, 1901.

The improvements in technique mainly apply to the observation tube and its introduction, as well as to the method of illumination. I consider the most important improvements as regards the tube since von Miculicz to be the introduction, without a "mandrin," of the short "tube spatula" with sloping end as practised by Killian, and in their replacement by my extensible double tube. By this means the entire œsophagus, even its reflexly contracted orifice (which von Hacker considered beyond the reach of laryngoscopy, and not yet within reach of œsophagoscopy), has for the first time been rendered accessible to direct inspection, and œsophagoscopy need no longer be commenced by blind feeling, but has become from the very outset a purely ocular method.

The problem of illumination has been principally advanced by Leiter (panelectroscope), Casper (manipulation of illumination), Brünings (broncho-electroscope, universal electroscope), Kirstein and Guisez (head-lights). When treating the question of syringoscopic illumination theoretically,* I think I have proved that exterior lamps of the construction which I employ are superior to any sort of interior lamp, and consequently I do not consider that anything is gained by illuminating the tube with small internal lamps (Einhorn, Schreiber, Jackson, Glucksmann, and others) or shining bars (L. von Schrotter). On the contrary, it appears to me that frontal lamps whose use is dependent on personal skill and practice may be replaced by an illumination of the tube with the electroscope, which is also suitable for operations and is self-acting.

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* "Über die Beleuchtungsprinzipien endoskopischer Rohre," *Verh. d. Ver. Südd. Laryngol.*, 1908.

The œsophagoscopic method has now been so far perfected that any surgeon can employ it without special preliminary training. Its eminent services are so generally recognized that the unjustified use of œsophageal probangs and blind extraction instruments, as also unjustified delays in the case of dangerous disease of the œsophagus, must in future be decidedly condemned. Laryngologists should assure themselves that a surgeon familiar with œsophagoscopic technique is always at hand, and it should be a duty of all such to practise œsophagoscopy diligently, since the general surgeon and the physician have, up to the present, treated this excellent method in so stepmotherly a manner.

A. THE ŒSOPHAGUS.

Œsophagoscopy, no less than bronchoscopy, presupposes an exact acquaintance with the normal anatomical and functional characteristics of the subject of examination. At the same time, the conditions, as far as they affect the method of examination, are much simpler in the case of the œsophagus than in the case of the complicated air-passages. The explanation may therefore be briefer. For the sake of clearness I shall discuss anatomical and physiological considerations separately, although it is not always possible to draw the line between them.

1. Anatomical.

The numerous works* on the morphology and topography of the œsophagus show the same divergencies as have been met with in the discussion of the anatomy of the air-passages. Although I have abstained from fresh investigations on the same lines as I applied to the air-passages—*i.e.*, orthostereoscopic Röntgen photographs after distension with gelatine—it was with the conviction that the divergent data of various authors is partly accounted for by the great actual variability in the structure of the œsophagus,

* A complete bibliography is to be found in Starck's textbook and in Gottstein's "Technik und Klinik der Oesophagoscopie," *Mitteilungen a. d. Grenzgeb. d. Mediz. u. Chirurg.*, Bd. 6, u. 8, 1901.

and partly by unavoidable and uncontrollable post-mortem changes. To this must be added the fact that numerically exact measurements cannot be obtained for the œsophagus, because in addition to the individual anatomical variations there are pronounced functional alterations of its condition.

POSITION AND DIRECTION.

Even the beginning of the œsophagus can only be determined functionally; consequently, anatomical pictures have not hitherto exhibited a uniform point of departure which can serve for measurements. Von Miculicz makes a distinction between an epipharynx, mesopharynx, and hypopharynx, but gives no definite boundary-line between the latter and the œsophagus. Killian was the first to show* that the tonic and sphincter-like occlusion of the superior extremity of the œsophagus is confined to the region of the lower border of the cricoid cartilage, where the lowest transverse bundles of fibres (pars fundiformis) of the constrictor pharyngis inferior form a lip-shaped prominence on the posterior pharyngeal wall (Fig. 87). This muscular band, whose sphincteric action can only be observed in the living body, thus represents the lower limit of the hypopharynx and the beginning of the œsophagus, the walls of which are supported in front by the cricoid plate, behind by the vertebral column, and at the sides by the more or less strongly developed lobes of the thyroid glands.

The cervical portion of the œsophagus occupies the median line between the vertebral column and the trachea, and with the latter enters the posterior mediastinum. As a rule the thoracic portion of the œsophagus, which begins here, now commences to swerve a little to the left of the median line, thus reaching the extramedian position of the pars diaphragmatica. The obtuse angle thus formed between the trachea and the œsophagus may, however, be quite absent, as in Fig. 88, or it may be due simply to the bifurcation swerving to the right. In contradistinction to the statements in the older anatomical atlases, the fact must be emphasized that the œsophagus does not wind up the vertebral column like a climbing plant, but that, on the contrary, its course is so straight that in certain circumstances a view of the lumen may be obtained from its commencement almost as far as the cardia.

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* "Über den Mund der Speiseröhre," *Zeitschr. f. Ohrenheilk.*, etc., Bd. 55, Heft 1 u. 2.

This fact, ascertained by direct inspection of the œsophagus, was confirmed anatomically by Mehnert.* He proved experimentally that curvatures of the œsophagus frequently arise from post-mortem conditions, chief among which are the altered position of the diaphragm (post-mortem formation of gases in the intestines), the varying weight of the stomach according to the amount of its contents, and the relaxation of the pharyngeal musculature.

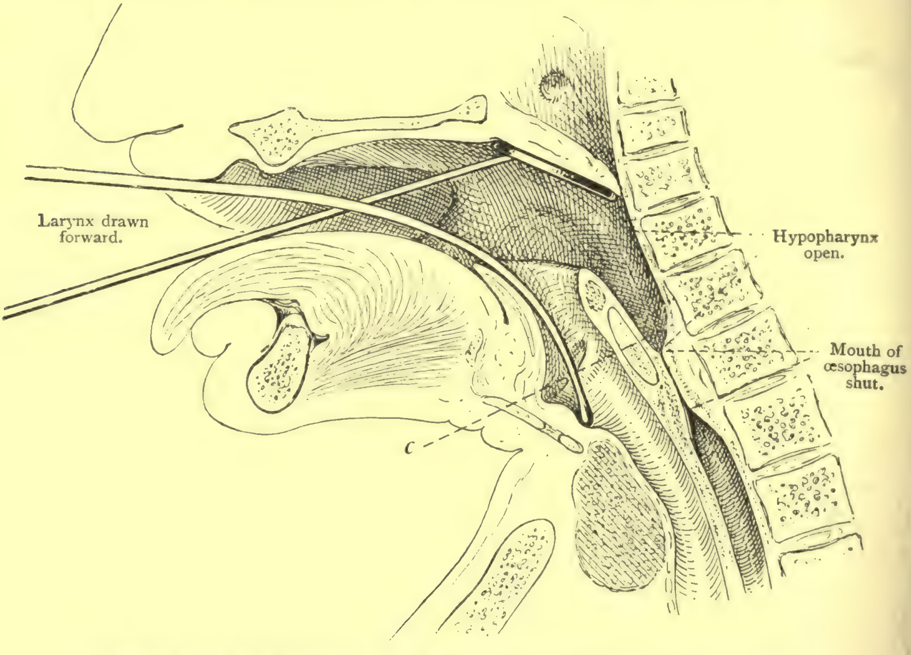

FIG. 87.—THE MOUTH OF THE ŒSOPHAGUS (HYPOPHARYNGOSCOPY). (After Killian.)

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* "Über die klin. Bedeutung der Oesophagus- und Aortendeviationen," *Arch. f. Klin. Chirurg.*, Bd. 58, S. 183.

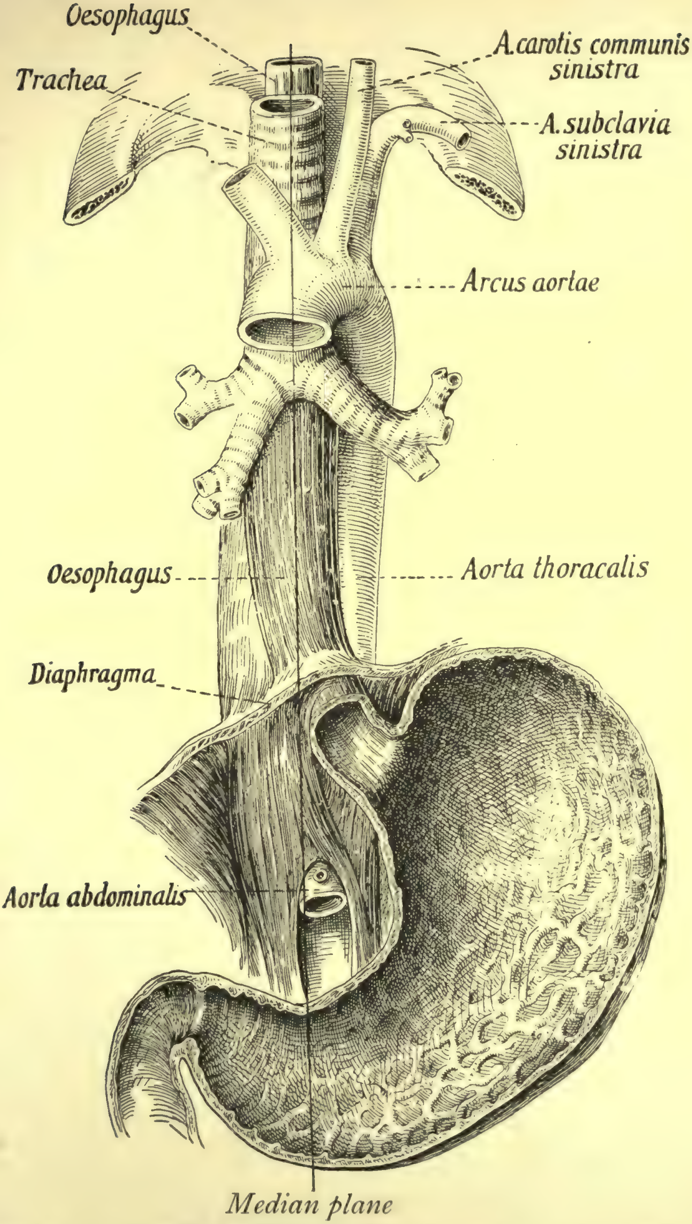

FIG. 88.—ŒSOPHAGUS, TRACHEA, AND AORTA (STOMACH MODERATELY DISTENDED).

The direction of the deviation in the thoracic portion is determined in living persons simply by the relation of the œsophagus to neighbouring organs; its left wall, and lower down its posterior wall, immediately adjoins the aorta, whereas the trachea, and below it the heart (left atrium), lie immediately anterior. From this can be explained pulsation phenomena which will be discussed later on.

There is a constant physiological curvature of the lower thoracic portion forwards and to the left (Fig. 88), which is important to bear in mind in direct examination. Immediately after the region of the bifurcation the œsophagus gradually assumes a position in front of the aorta, thus getting away more and more from the vertebral column. The extramedian position of the œsophageal opening is determined by the oblique passage through the diaphragm owing to the crossing of the crura, so that it is gradually shifted from 3 to 5 centimetres to the left at the point where it enters the stomach at the cardia.

To illustrate the curvature in a dorso-ventral direction (seen imperfectly in Fig. 88), I have in Fig. 89 shown a drawing by von Miculicz, from which the relations in the sagittal direction can be seen. The forward curvature of the pars diaphragmatica and the pars abdominalis here appears to be so considerable that the appropriateness of the lower curve of von Miculicz's gastroscope is quite obvious. It is clear from this picture that the straight œsophagoscope introduced into the distended stomach must pass close along the posterior wall or in the angle between the posterior wall and the lesser curvature.

Without doubt, the course of the pars diaphragmatica and the pars abdominalis greatly depends upon the degree to which the stomach is filled, because the latter extends mainly forwards and to the left, and owing to its variable weight tends to drag the œsophagus into a straight line. This appears to me to be the chief reason why it is easier to reach the stomach when the patient is sitting than when he is lying down, and why when he is lying down it is preferable for him to lie on his right side.

The variable degree of mobility of the several sections of the œsophagus are of practical importance as regards examination. It is only the region of the upper œsophageal orifice which is comparatively fixed, but the movements of the pharyngeal musculature in deglutition, as indicated by the rising of the larynx, shows that it must be partly a fixation caused by reflex muscular contraction. As a matter of fact, the passive mobility of this region is considerably increased during anæsthesia, so that, according to Jackson,*

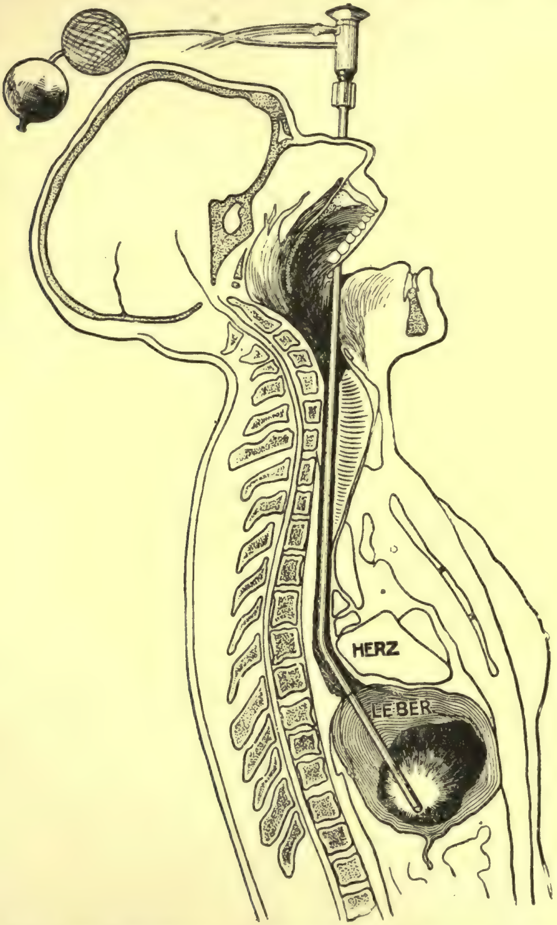

FIG. 89.—ŒSOPHAGUS AND STOMACH IN SAGITTAL SECTION. (After von Miculicz.)

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* *Tracheo Bronchoscopy, Œsophagoscopy and Gastroscopy*, St. Louis, 1907.

the tube can make lateral excursions several centimetres in extent.

Lower down, the extremely loose tissue of the cavum mediastini admits of a considerable lateral displacement, the amount of which is only somewhat limited in the neighbourhood of the bifurcation by its rather more solid connection with the pericardium and the peribronchial connective tissue, whilst farther still, near the diaphragm, it decreases considerably. The mobility of the second relatively fixed point of the œsophagus—viz., the hiatus œsophageus—depends, of course, very greatly on the state of contraction of the diaphragm. In muscular and corpulent subjects, the mobility is always much less than is the case in lean and weakly ones. It almost disappears when the patient strains or breathes convulsively, while, on the other hand, Jackson was able to displace the hiatus by 15 centimetres laterally, and 5 centimetres in a dorsal-ventral direction, in a patient who was deeply anæsthetized.

A long series of autoptic and endoscopic measurements have been carried out in order to locate topographically the upper end of the œsophagus and especially the cardiac orifice, but the only certain result has been to show that both regions are very variable. In Chapter IV. has already been said all that was necessary regarding the larynx and especially the cricoid plate, to the position of which the beginning of the œsophagus bears a constant relation. The bifurcation of the trachea has also been dealt with. Gottstein has collected all the literature bearing on the topographical relation of the cardia to the vertebral column, and has thus arrived at mean values showing that its position most often coincides with the ninth, tenth or eleventh thoracic vertebra.

The reasons for the great variability that is found in the cadaver have been mentioned above. In the living subject, apart from the physiological dropping of the intestines through age, a great rôle is certainly played by the varying traction exerted by the stomach, according as it is more or less distended by food. As it is unlikely that the short abdominal portion can be greatly elongated, it must be assumed that the hiatus œsophageus is capable of great vertical displacement.

RELATIVE PROPORTIONS.

The pronounced topographical variability makes intelligible the fact that the longitudinal measurements of the œsophagus may differ greatly. From Starck's summary of the literature on the subject, I find that the anatomical length of the œsophagus (from superior edge of the cricoid plate to cardia) is stated by ten different authors as from 20 to 35 centimetres. The number 25 occurs most frequently, and may therefore be taken as the mean value. There is not even an approximately constant relation to the size of the body, as in the case of the trachea, although no doubt its length does vary with the length of the body, and is generally greater in men than in women.

For practical purposes it is more important to know the several distances, reckoning from the upper row of teeth, because, when using the œsophagoscope, they may be a help in orientation and a guide to the location of endoscopic findings. The following tables contain the numerical data of von Hacker, which are based upon a long series of endoscopic measurements.

In connection with the figures relating to children, it must be observed that in many cases they only represent a single measurement, so that individual variations are not shown. Nevertheless, this table serves as a valuable guide, and will enable any serious error of localization to be avoided.

LENGTH OF THE ŒSOPHAGUS.

ADULTS.

	Men.			Women.		
	Degree of Variation.	Mean.	Usual Observation.	Degree of Variation.	Mean.	Usual Observation.
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
From teeth to mouth of œsophagus	14-16	14·9	15	12-15	13·9	14
From teeth to bifurcation	23-29	26	26	22-27	23·9	24
From teeth to cardia	36-50	39·9	40 and 41	32-41	37·3	38 and 39

LENGTH OF THE ŒSOPHAGUS (*continued*).

CHILDREN.

Age.	From Teeth to Mouth of Œsophagus.	From Teeth to Bifurcation.	From Teeth to Cardia.	Length of Whole Œsophagus.	Length of Suprabifurcal Part.	Length of Infrabifurcal Part.
	Cm.	Cm.	Cm.	Cm.	Cm.	Cm.
9 days	7	12	17	10	5	5
6 weeks	6	11	18	12	5	7
3 months	7·5	12·5	19	11·5	5	6·5
3½ months	8	13	20	12	5	7
14 ,,	10	14	22	12	4	8
21 ,,	10	15	23	13	5	8
2 years	—	—	—	13·5	5	8·5
2 ,,	9	16·5	24	15	7·5	7·5
3 ,,	—	—	—	14	6	8
4 ,,	—	—	—	15	6	9
5 ,,	10	17	26	16	7	9
6 ,,	11	19	28	17	8	9
9 ,,	—	—	—	16	7	9
9 ,,	11	19	27	16	8	8
11 ,,	10	18	28	18	8	10
12 ,,	10	18	28	18	8	10
14 ,,	11	19	31	20	8	12
15 ,,	14	23	33	19	9	10

Most important are the measurements in adults, and especially the knowledge of the fact that in the case of men the cardia may in some be reached 36 centimetres from the teeth, whilst in others the cardia may be 50 centimetres distant. It is found, too, that the "normal" distance of 40 centimetres is subject to extraordinary variations. In women the corresponding numbers are 32 and 41, giving a mean of 38. I should add that measurements with flexible probes and elastic bougies without the employment of pressure generally give values of from 1 to 3 centimetres in excess of these numbers, owing to the various curvatures met with.

It is important also to know the distance in a straight line between the teeth and the mouth of the œsophagus. It does not vary much, and is about 15 centimetres in men, and 14 in women. Tracheoscopy has already shown that the distance from the teeth to the bifurcation is 26 centimetres in men, and 24 centimetres in women.

Although these measurements were of great importance in selecting a suitable tube when former œsophagoscopes were employed, it is only necessary to take into account the width of the œsophagus when my extensible tubes are employed. It is certainly not possible to speak of any fixed diameters, because, on the one hand, in œsophagoscopy tonically contracted sphincters have to be overcome, and, on the other hand, even the narrowest parts are capable of considerable dilatation. Jonnesco (quoted from Starck) finds, in the case of measurements of the œsophageal orifice made on the cadaver, a transverse diameter of 23 millimetres (with slight distension), while the sagittal diameter is given as 17 millimetres. The diaphragmatic constriction at the beginning of the hiatus œsophageus is said to be more circular in section, and to present diameters of 25 and 24 millimetres in the above directions.

In practice—*i.e.*, for the choice of a tube of requisite thickness—these numbers are of little use, and to von Hacker's view, that 13 millimetres is the greatest diameter of the tube permissible for the cricoid constriction, I should like to oppose the fact that, even in normal deglutition, foreign bodies of much greater dimensions and of no easier deglutition can pass this spot. Besides extracting large dentures, I have myself, with the aid of the dilatation œsophagoscope (see p. 295) easily passed a fragment of bone through the orifice of the œsophagus while opening the instrument to the extent of at least 30 millimetres. It might be possible to pass the conical form of dilator through the upper contraction without danger, even when extended to its maximum of about 5½ centimetres in transverse section. If it is not usual, in œsophagoscopy, to exceed 14 millimetres as the thickness of the tube, this limit is not imposed by the dimensions of the upper end of the œsophagus, but by the drag forwards owing to the pressure against the upper teeth (see p. 263). A much greater dilatation laterally would be possible, as two stomach tubes can, without difficulty, be introduced side by side.

For this reason, Starck employs in certain cases tubes with oval transverse sections such as Kussmaul and Schreiber used before him.

The diaphragmatic constriction also admits of an enlargement much in excess of the anatomical measure. In von Miculicz's operation for spasm of the cardia, rapid dilatations up to 7 centimetres have been effected, giving the hiatus the enormous circumference of some 16 centimetres, equivalent to a circular cross-section of about 53 millimetres.

Between the cricoid constriction and that at the diaphragm, impressions on the left anterior wall of the œsophagus in the neighbourhood of the tracheal bifurcation are met with. These are caused by pressure of the aorta and the left bronchus, and are called the "aortic" and "bronchial" constrictions. There is no complete obliteration of the lumen, as at the two ends of the œsophagus. On the contrary, during œsophagoscopy, with the tube above this point, a pulsating swelling crossing the left anterior wall is all that is seen. The bronchial impression immediately below it takes a descending direction from right to left. It frequently happens during œsophagoscopic exploration that these constrictions are only faintly indicated, and it is only as the tube is advanced that the increased resistance and sensible pulsation of the anterior wall enables the position of neighbouring structures to be perceived. The constriction due to the tracheal bifurcation stands out very clearly if the yielding portions of the œsophagus are distended by blowing in air (see p. 291).

The wall of the œsophagus in the collapsed state is of considerable thickness. If moderately distended, the diameter of the muscular coat (internal circular and external longitudinal layer) and of the mucosa + submucosa each amount to about 1·5 to 2 millimetres, which gives a total thickness of from 3 to 4 millimetres. Owing to the great capacity for displacement of the submucous tissue, the muscular coat is not easily perforated when an injury occurs, or in the case of clumsy excisions of pieces of mucosa.

2. Physiological.

From the point of view of œsophagoscopy, the main interests in the functional properties of the œsophagus lie in the phenomena of its movements, and more especially the act of swallowing. It seems necessary to discuss this important reflex process carefully, because, as will be seen, the understanding of it is of great importance, both from the point of view of œsophagoscopic technique and of the interpretation of pathological findings, and also because physiological manuals often omit proper mention of it.

When the tonic contraction of the orifice of the œsophagus was mentioned, a physiological process which may be regarded as a part of the extremely complicated act of swallowing was referred to. Generally speaking, this regular reflex act partakes of the mechanical character of a peristalsis—*i.e.*, a progressive wave of contraction spreading along the muscular wall of the œsophagus, as is usually the case when forward motion is brought about in tube-shaped organs. In the mouth and in the pharynx, however, owing to the complicated conditions of space and the unavoidable voluntary influence, the process becomes less simple.

The act of swallowing is begun voluntarily by the tongue pushing the bolus of food against the palate behind the anterior palatine arch. At the same time the pharynx shapes itself like a funnel, with its mouth directed to the œsophagus, the naso-pharynx being shut off by the lifting of the velum palati, the contraction of the posterior palatine arches and of the constrictor pharyngis superioris (Fassavant's pad); while the root of the tongue, turning over behind, with the epiglottis covers the aditus ad laryngem, which is already narrowed by the approximation of the aryteno-epiglottic folds and the ventricular bands. The larynx is then strongly drawn upwards towards the hyoid bone through contraction of the M. thyreo-hyoideus, and at the same time both are moved forwards away from the vertebral column by the action of the muscles of the floor of the mouth (Genio- und Mylohyoideus, Digastricus ant.). In this way the pharyngeal funnel ending in the œsophagus is formed, whilst the progressive contraction of the constrictors moves the bolus forward peristaltically.

The final process is involuntary, although accomplished through the agency of striated muscles. This process cannot be normally initiated by intentional swallowing movements of the tongue (empty swallowing), but requires, as a reflex provoking stimulus, the contact of the bolus with the posterior palatine arches of the root of the tongue and the pharyngeal wall. This reflex action is produced even when the cerebrum is cut off; it is equally impossible to arrest the act of swallowing voluntarily when it is once begun. It is usually an abnormal reflex stimulus, or psychical impressions, which interrupts or reverses the progress of the bolus by inducing reflex vomiting.

The opening of the orifice of the œsophagus when it has been contracted tonically is of special importance in the pharyngeal phase of the act of deglutition (Killian). That this is a case of reflex tonic inhibition, and that it is not the upward and forward movement of the larynx alone that causes the hypopharynx to open, is shown by its behaviour during hypopharyngoscopy (see Fig. 87, p. 230). Tonic contraction of the œsophageal opening resists even a strong forward pull, and it is never possible to open it forcibly. When introducing probes and tubes, there is always a more or less passive dilatation, as it is, unfortunately, impossible to effect a sufficient active opening by empty swallowing or by the swallowing of small quantities of saliva, difficult as that is when an instrument is introduced. It would appear, indeed, that the degree of such opening bears a strict proportion to the size of the bolus swallowed.

If the movements of the floor of the mouth, of the soft palate, the hyoid bone and larynx, and the contractions of the pharyngeal constrictors are taken together, and described as the bucco-pharyngeal phase of the swallowing act (Zwaademaker and Kindermann),* the further progress of the bolus may be called the œsophageal phase. This also is of the nature of progressive peristaltic contraction, the rapidity of which is far greater in the upper and striated third of the œsophageal muscular tube than in the lower two-thirds. From Kindermann's curves, it would seem that the bucco-pharyngeal phase lasts about 0·75 second, and the œsophageal phase about 6 seconds. Of this, only 1·75 seconds belong to the cervical part of the œsophagus but 4·5 seconds to the thoracic portion. These varying rates of speed may be readily seen on the Röntgen screen when pieces of bismuth are swallowed.

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* *Ned. Tijdschr. v. Geneesk.*, ii., Nr. 21, 1903; also reference from Burger, *Zentralbl. f. Laryngol.*, Bd. 26.

The peristaltic action of the œsophagus does not appear to be of much importance when food is taken in the ordinary way, as soft morsels and, still more liquids, always reach the stomach sooner than the following wave of contraction (Kronecker and Meltzer.)* As regards the latter, no doubt the spreading contraction of the pharyngeal musculature suffices to convey them to the stomach directly with the velocity which is known from auscultation of swallowing. The "second sound of swallowing," which is heard later, corresponds to the sluggish contractional wave, which in quick drinking does not follow on each separate act of deglutition, but only after marked intervals. Killian has pointed out that well-trained and fast drinkers (*Bierjunge*) are able, after the first start, to allow the liquid to flow down in one uninterrupted stream, and that, accordingly, the inhibition of the œsophageal orifice may, through suitable practice, assume a continuous character. It is important to mention that not only solid food, but even liquids, may be swallowed while a person stands on his head, so that it appears that the circular musculature of the œsophagus is capable of continuous water-tight contraction. The great force of the peristaltic movement is shown by an experiment by Mosso, who found that dogs were able to swallow wooden balls even when a counter-pull of from 250 to 450 grammes was applied.

The peristaltic waves of contraction may be observed very clearly with the œsophagoscope. A complete sphincter-like wave of contraction passes sluggishly over the lumen, so that in each succeeding section the lumen is obliterated for several seconds. I have frequently and conclusively proved that these waves may arise spontaneously without any visible cause (food or liquid), and without any preceding and voluntary act of swallowing. The statements contained in the physiological manuals* are certainly incorrect and incomplete on this point, and the question of spontaneous or autochthonous contractions of the œsophagus, so important in the pathology of foreign bodies, spasms, pareses, and dilatations, requires to be examined afresh.

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* *Arch. f. Anat. u. Physiol.*, Supplement Band, 1883.

It is certain that normally the inner surface of the œsophagus responds far less to chemical, osmotic, thermal, electric, and mechanical stimuli than does the rest of the intestinal tract.

I was not able to produce autochthonous contractions either through cauterization with silver nitrate, or with concentrated solution of common salt, or with rocksalt crystals, which so powerfully affect intestinal peristalsis. I found that the contact of liquids from 45° to 50° was equally ineffective; and on using the electric current, which in the thoracic section must, of course, be applied in the galvanic form, I was only able to produce a local contraction of the muscles by means of 16 volts and electrode interval of 1 to 2 centimetres. I have not examined the cervical portion; as it possesses striated muscles, it may be expected to show considerable faradic irritability, but this likewise only results in local contractions. (The reason why an annular contraction or progressive peristalsis is not obtainable by this means may be that the electric stimulus simultaneously affects the annular and longitudinal muscles, which to some extent operate antagonistically.)

The fact that a tube may be introduced without difficulty proves that no noticeable mechanical irritability exists, and also helps to show why the morsel of food introduced œsophagoscopically remains in its place until pushed forward peristaltically in consequence of a voluntary act of swallowing. This, however, no doubt applies only to small pieces of food, for I have found that a mechanical stretching of the wall of the œsophagus results in a strong and uninterrupted peristalsis.

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* Landois says in his *Textbook of Physiology*, 10th edit., p. 303: "The movements of the œsophagus are not originated by the organ itself, and do not occur spontaneously, but are closely bound up with the existence of a definite swallowing movement. If a bolus is placed in the tube through an external œsophagotomy wound it remains where it was placed and only moves downwards when a definite swallowing movement supervenes" (Volkmann).

This phenomenon can best be watched by inflating the œsophagus through an œsophagoscope (see p. 291) closed with a glass disc. A slight inflation suffices to produce the first contractions, and these succeed one another at shorter and shorter intervals. Each wave appears as a fairly sharply-marked annular contraction, which on stronger inflation no longer causes occlusion of the lumen, but moves downward as a circular diaphragm 1·5 centimetres in diameter. These rings of constriction often succeed each other at intervals of less than a second, so that through their lumen several of them may be seen simultaneously.

To enter further into the physiology of this inflation peristalsis would lead too far, and for this reason I will also abstain from discussing its importance in relation to the pathology of foreign bodies, stenoses, and dilatations, but should, however, like to point out that this method may possibly be applicable when pathological changes in irritability (spasms and pareses) are being examined, and might enable the surgeon to decide whether the cause of disturbances produced is to be sought in the wall of the œsophagus or in the central organ.

I have not been able to observe any antiperistaltic movement of the œsophagus, either produced spontaneously or by artificial stimuli. That physiologists deny the possibility of real antiperistalsis with regard to the intestines is well known. At any rate, the processes of rumination, regurgitation, and vomiting, may be explained simply as the effect of the abdominal pressure, the expiratory pressure, and the contraction of the stomach.

The vomiting which occurs on dilatation of the œsophagus when the stomach is moderately filled is, no doubt, the result of distension peristalsis. For the waves of constriction moving in a normal direction, but not producing complete occlusion, only result in a diminution of the lumen, and the contents, following the path of least resistance, can still be voided through it.

There has been much discussion as to whether the cardia is a tonically contracted muscular sphincter like that at the upper end of the œsophagus, or is merely of a valvular nature (or both, von Miculicz). No doubt the contradictory œsophagoscopic discoveries have been complicated and confused by the fact that the pars diaphragmatica, compressed by the crossing fibres of the crura, is more or less firmly closed by their pressure, and by the fact that the pars abdominalis is so obliquely placed that its lumen can seldom be presented to the tube. Finally, as Jackson assumes, the varying degrees of stomach distension may give rise to a sharp kinking in the region of the hiatus œsophageus.

The fact that it is easily possible to reach the stomach with thick flexible tubes, whereas a rigid tube meets with a resistance which varies much with the subject, seems to show that the muscular constriction is not very tight, to say the least of it, and that resistances presented are due rather to imperfect congruity between the direction of the tube and the course of the organ. On the other hand, of course, the cardia occlusion (controlled by the sympathetic) must suffice to prevent the regurgitation of food and liquids, and it may do this so effectively in pathological cases (cardia spasms) that even the normal passage of liquids is stopped.

In this connection the following experiment is noteworthy: Through an œsophagoscope introduced beyond the bifurcation, I carefully filled the œsophagus, by means of a long pump tube, with normal saline at body temperature which flowed regularly into the stomach without giving rise to any peristalsis whatever. It appears also that a relative distension of the stomach does not interfere noticeably with the passage of liquids, for the experiment was in no way altered even after $\frac{3}{4}$ litre had been introduced into the stomach. Cold water gave a like result, even when the experiment was carried out in a nearly horizontal position. It is remarkable that, when inflating with air, a rather greater pressure seems to be necessary for the air to reach the stomach—viz., 1 to 1·5 millimetres Hg. It cannot, however, be determined exactly on account of respiratory, pulsatory, and peristaltic variations. The filling of the œsophagus with water might possibly be a good means of testing motor anomalies of the cardia, and might also be useful in ascertaining its capacity for dilatation.*

With regard to the innervation of the swallowing mechanism, I will only observe that, generally speaking, the sympathetic is considered as the constrictor, and the vagus as the dilator, of the œsophagus. The cardia innervation is supposed to be so inseparably connected with the bucco-pharyngeal process of swallowing that its normal tonus is temporarily inhibited at every act of swallowing. Very probably the phenomenon of summation may here occur, the cardiatonus being inhibited when several acts of swallowing occur in rapid succession, and the resulting relaxation thus becoming more complete. Whether the cardia is opened reflexly in the case of œsophagus peristalsis arising autochthonously is not known. This question deserves to be more closely examined with a view to explaining spasmodic dilatations.

The paths of the sensory stimulus which initiate the act of swallowing are through the palatal branches of the fifth nerve and the R. laryngeus sup. vagi, and the centre is situated in the medulla. As the reflex is under central control, the deglutatory peristalsis is not interrupted when the continuity of the œsophagus is broken. It would lead too far were the nervous relations to be examined, as these, though very important pathologically, are as yet not well explained.

RESPIRATORY MOVEMENTS.

When von Miculicz in 1881 looked down the œsophagoscope for the first time, he thought that he had a patient afflicted with paralysis of the œsophageal muscles. Instead of the collapsed fissure figured in anatomical atlases, he saw an open tube with a very wide lumen. Subsequent investigations soon convinced him that in the living subject the normal œsophagus gapes as far as the cardia, and is filled with air. By means of examinations carried out on corpses, it was further ascertained that on opening the pleura the lumen immediately disappears. The explanation of this surprising phenomenon is that the negative pressure of the thorax unfolds the yielding œsophagus in the same manner as it does the lung.

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* *Note during Correction.*—I see that in v. Miculicz's clinic the filling of the œsophagus with liquid has been used in order to ascertain the degree of dilatation (Gottstein, *Mitteilungen a. d. Grenzgeb. d. Mediz. u. Chirurg.*, Bd. 6 u. 8).

In spite of this apparently very plausible explanation, I have investigated the question of air content experimentally, as, up to the present, it has only been proved that the œsophagus is found filled with air after the introduction of an open tube, and it is not known that this is also the case in ordinary circumstances.

There are, indeed, serious difficulties in the way of such an assumption. In the first place, it is surprising that the suprabifurcal portion of the thoracic section never shows any shading off in a skiagram, although its diameter is scarcely inferior to that of the trachea. Then, too, there is the question as to what becomes of the air in the œsophagus when there is positive pressure of the thorax (coughing, straining, etc.), as the sphincters cannot possibly resist pressures which may be as high as one atmosphere. Also it must be supposed that any large morsel carried down by peristalsis would act like the piston of a syringe, and would push the air of the œsophagus into the stomach. Consequently, if there was a new supply each time from without, then—assuming an œsophageal content of 50 c.c. —the stomach would be inflated with 1 litre of air after twenty morsels.

At present, therefore, I assume that the air content visible during œsophagoscopy only occurs in consequence of the introduction of a tube, as, when there is free communication with the outer air, the atmospheric pressure must in fact unfold the wall of the œsophagus until its elastic resistance balances the negative thoracic pressure due to the lung elasticity. This assumption, however, cannot be demonstrated experimentally. When I used an œsophagoscope with closed tube to avoid all fresh entrance of air, I nevertheless always found the œsophagus gaping. Further, with a soft air-tight sound it was always possible to withdraw a certain quantity of gas from the œsophagus. Moreover, oxygen which was injected and again removed (by means of phosphorus) could only be partly burnt, in consequence of its being diluted with non-inflammable gases.

These three experiments certainly prove conclusively that the œsophagus contains air or gas independently of the introduction of the œsophagoscopic tube. Nevertheless, the above-mentioned contradictions are not set aside by this evidence. It especially remains to be explained how the air acts during eating and when there is over-pressure within the thorax. I think that the following experiment throws some light upon it. If a person swallows a large piece of bread whilst lying on his back, and then gets up, he invariably ejects a considerable quantity of air, but this does not happen when food is taken in the upright posture. Further, in the lying position air can as a rule only be withdrawn from the œsophagus by means of a tube, whereas in the upright position this may often be done several times.

The experiment may quite naturally be interpreted to mean that when solid food is taken air is really swallowed, but that, in consequence of the constant positive pressure in the stomach, it immediately recedes into the œsophagus. In the lying position this is rendered difficult or impossible, because in this case the cardia enters the most dependent part of the stomach. Surgeons are also familiar with the fact that invalids have difficulty in taking food in a horizontal position, and that the process is often interrupted by eructation. This leads to a reasonable assumption regarding the behaviour of the œsophageal air during straining; if this is accomplished solely by the diaphragm and walls of the stomach, any air present in the stomach must get into the œsophagus—if the position of the cardia allows of it—and voluntary eructation may follow. Simultaneous thoracic pressure would be able, on the other hand, to compress the œsophagus, so as to make it completely impervious. On these grounds, it would appear that during vomiting the increase of pressure is purely abdominal.

I believe that this explanation with regard to the behaviour of air in the œsophagus is quite satisfactory. Von Miculicz also investigated the question as to whether the wall of the œsophagus is prevented from collapsing by fixation to neighbouring organs. As a matter of fact, the œsophagoscope shows that the size of the lumen may, indeed, vary with respiratory movements, but that only a great increase of intrathoracic superpressure could bring about complete occlusion. I was able to show by the following experiment that the air of the œsophagus nevertheless followed the movements of the air in the lungs quite passively. If a soft catheter is introduced into the thoracic portion, and if the outer curved end is put into the patient's mouth (by means of a doubly pierced cork), he is neither able visibly to inflate his own œsophagus by expiration nor to deflate it by inspiration.

The respiratory movements rendered visible by the œsophagoscope show that an expansion of the lumen occurs on inspiration, and a narrowing of the same by expiration, the amount being proportional to the variations of pressure within the thorax, after allowing for the elastic resistance of the wall of the œsophagus. Sudden or obstructed respiratory movements therefore bring about maximum expansion or complete occlusion. These variations in the size of the lumen cannot, of course, make themselves felt equally in all sections; they are absent near the mouth of the œsophagus, and very slight in that portion of the cervical œsophagus which is just above the dome of the pleura. The constrictions due to the tracheal bifurcation and to the aorta cause increased resistance, and are consequently more distinctly visible when inspiration is violent and laboured.

The variations in the lumen during respiration are a great asset in the technique of examination, since the inspirational enlargement enables the direction of the lumen to be ascertained, and aids in the recognition of stenoses, whilst greatly increasing the field of vision and the possibility of seeing the deeper parts. An attempt should be made therefore from the outset to combat the constant inclination to forced expiration, and the patient should be encouraged to make deep inspirations during all important diagnostic and therapeutic processes. The direction of these pulsations, which at the level of the bifurcation run laterally, and below this dorso-ventrally, is explained by the topographical situation of the aorta and the heart. They have been successfully utilized (Minkowski and others) for the study of the heart's action, by the introduction of registering sounds.

B. GENERAL PREPARATION.

Following my procedure in the chapters on direct tracheo-bronchoscopy, I shall first discuss some questions the consideration of which would interrupt the continuity of the subject. I mean the choice and composition of a set of instruments, asepsis, contra-indications in and preliminary examination of the subject, and these I include under the heading General Preparation. If some of these questions are only lightly touched upon, it is for the reason that their answer may be deduced from the previous chapters on the direct examination of the air-passages.

1. Set of Instruments.

The set of instruments required in œsophagoscopy is in all essential points the same as in tracheo-bronchoscopy, and it therefore suffices to refer to what was said before. For those readers who intend to confine themselves exclusively, or at least mainly, to the examination of the œsophagus, some special hints may be useful concerning illuminating apparatus, forceps, and tubes. For them a simpler collection of instruments is required.

The relatively easy illumination of the wide œsophagoscopic tube, and the smaller requirements in the grip, make it unnecessary, for exclusively œsophagoscopic work, to procure the complicated broncho-electroscope. In these cases my more handy universal electroscope (see Fig. 83) should have the preference, as, in spite of its simple construction, it entirely fulfils all the requirements of œsophagoscopy. Investigators who are familiar with the endoscopic use of forehead lamps can employ this mode of illumination much more easily in œsophagoscopy than in tracheo-bronchoscopy, as in the inspection of the œsophagus—especially if a tube is introduced blindly with the mandrin—no complicated movements usually take place. If, however, I still advise the beginner to employ the electroscope, it is for the reasons mentioned above in Chapter III.

The tubes that usually suffice for all purposes are No. 3 (10 millimetres), No. 4 (12 millimetres), and No. 5 (14 millimetres). It is, however, advisable, as specially useful in œsophagoscopy, to have No. 3 provided, in addition, with a longer internal tube without a window, like the one supplied for use with No. 4 in the normal set of broncho-œsophagoscopic instruments. With these three tubes all the necessary lengths can be produced, and, owing to the great elasticity of the œsophagus, it is unnecessary to obtain tubes of many different degrees of thickness. For this reason, in the normal set of instruments, only the three widest spatula tubes are provided with the special bougies as mandrin for introduction.

For direct hypopharyngoscopy it is generally sufficient to have the three spatula tubes, but the introduction and presentation are facilitated by the so-called "window-tube" (see p. 282), especially where diverticula exist.

I have shown fully elsewhere* that the principle of my extensible double tube, originally constructed for tracheo-bronchoscopy, is in many ways preferable to the simple tube used hitherto. Apart from the fact that, in contrast to the usual four lengths (20, 30, 40, and 50 centimetres) for each diameter, only one is now required, there are also the two following far more important advantages of method:

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* "Über Fortschritte in der Osophagoskopischen Behandlung verschluckter Fremdkörper," *Deutsche Mediz. Wochenschrift,* No. 17, 1909.

1. The double tube can easily be introduced by means of the spatula-tube, without mandrin and under the direct control of the eye.

2. If the seat of the affection is unknown or varies, it is possible, with the help of the extensible double tube, to avoid exploratory probing or repeated introductions.

The practical importance of these qualities will be realized more fully when actual examinations are carried out.

So far as œsophagoscopy alone is concerned, the extensible bronchoscopic forceps with the five end-pieces may be dispensed with, but I should recommend, in addition to an extensible œsophagoscopic forceps with the three ordinary end-pieces (claw forceps, bean forceps, double curette*), the purchase of a short and specially strong claw forceps for the extraction of foreign bodies which are firmly impacted in the cervical part. If my new slotted mirror is used, two simple forceps of the permanent lengths of about 25 and 50 centimetres, with interchangeable end-pieces, will suffice.

As regards instruments for probing and dilatation, general reference may be made to the dynamometric dilator for the œsophageal orifice and cardia, medicament-carrier, etc. For the diagnosis of an œsophageal pouch, and especially for discovering the direction of the œsophagus, it is well to have a special probe with at least two end-pieces of different curvature.

All the œsophageal instruments (forceps, wool-carriers, pumps, and probes) must be capable of attaining a practical length of 50 centimetres. As, however, for use in the cervical section of the œsophagus and for children it is necessary that the instruments should only measure 25 centimetres, it is advisable to have those instruments which are not extensible in lengths of about 25, 35, and 50 centimetres.

To complete an œsophagoscopic equipment, there must also be a suitable operating-table. It is much more important in this case to have a contrivance for lowering the head than it is in bronchoscopy, because this alone enables the secretions and douches of the œsophagus to be got rid of. With regard to its construction, I should like once more to point out that a mechanism whereby the foot-end is raised appears to me much more rational than the usual mechanism of a central pivot.

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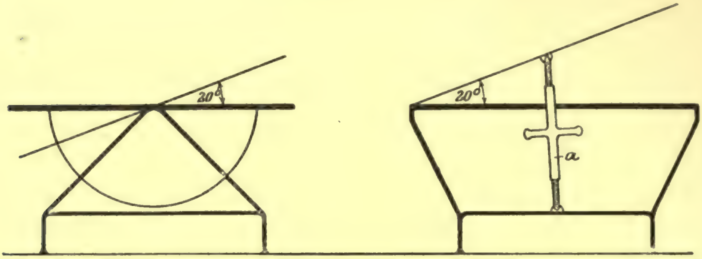
* For the experimental excisions from tumours situated high, the punches intended for direct laryngeal operations may be employed. But in general it is better to use the non-cutting double spoon, because, if properly used, it only attacks pathological tissues.



No. 1. No. 2.

Fig. 90.

Fig. 90 indicates the two arrangements, and shows that in the case of No. 1 (Starck's surgical table) a very considerable general lifting of the table is necessary in order to equalize the lowering of the upper part of the body which occurs with each inclination. Starck's table may be raised for this purpose as much as 135 centimetres, thus rendering the use of a small ladder necessary.

The arrangement shown in No. 2 seems to me simpler. A pivot, *a*, provided with a screw-shaft turning left and right, renders possible a smooth and secure lifting of the lower end of the body during examination. If the table-top is upholstered, the patient will be much more comfortable; the best thing to prevent slipping is a rough cover of wool or felt securely fixed.

For convenience I will enumerate the articles composing a normal outfit for œsophagoscopy only:

1. A universal electroscope with spare burners and coil.
2. The extensible double tubes No. 3 (10 millimetres), No. 4 (12 millimetres), and No. 5 (14 millimetres), with long windowless inner tubes.
3. Special bougies as mandrins for the three tubes.
4. Three forceps, respectively 25, 35, and 50 centimetres in length, with three interchangeable end-pieces (claw forceps, bean forceps, double curette), or two extensible forceps with the above end-pieces.
5. A saliva-pump with three different lengths of tube.
6. A dozen double wool-carriers; bullet-probe.
7. Three roughened probes (wool-carriers) for applying cocaine, or one painting syringe.

The following instruments may also be mentioned as being useful:

Extraction dilator for impacted foreign bodies (see p. 295).
Two pneumatic tubes for examinations with air inflation (see p. 291).
Long probe with olive end, and two curved ends for diverticula.
One set of bougies with wire guide for the treatment of stenoses.
A set of bougies for retrograde bougieing (see p. 299).
Dynamometric dilators for treating spasm of the œsophagus—cardia and mouth of œsophagus.
Window beak-tube for exploring diverticula (see p. 282).
Medicament-carrier; endoscopic telescope.
Jet aspiration-pump; washing apparatus (Ingram syringe).

As regards the general manipulation and testing of the instruments, as well as practice on a dummy, I may refer to what was said in Chapter I. Starck recommends that preliminary practice should take place on dogs, and describes the procedure. It may be that in œsophagoscopy practice on living animals is of greater value than is the case in bronchoscopy, since the introduction of the tube is not so difficult, but I have had no personal experience in the matter. At all events, I should advise that no experiment be made on human subjects until the use of the instruments has been fully mastered.

Special instrumental preparations for particular cases are much simpler than in direct tracheo-bronchoscopy, but still the principle should be followed of arranging everything with pedantic thoroughness, so as to reduce the duration of tube introduction to a minimum and to avoid any unnecessary repetition. In œsophagoscopy the operator has to be prepared for the field of vision being obscured by saliva, blood, or the contents of the œsophagus or stomach, and for this reason not only a saliva-pump but also a considerable number of mounted swabs should be kept in readiness. In extreme cases, such as a loaded stomach, œsophageal dilatation, large diverticula, it may be necessary to wash out the œsophagus; this may best be accomplished by using a very small stomach-tube, or better still by means of a nasal douche syringe (Higginson's), connected with a pump-tube. The table must in this case be tilted enough to allow the water to run off into a bucket placed underneath.

The choice of the right tube is generally quite obvious. In the case of adults I generally advise the use of the medium one (No. 4, 12 millimetres). Only in cases where œsophagoscopy is particularly easy (see later on), or for difficult operations far down, should the strong tube (No. 5, 14 millimetres) be employed. In the case of children or of specially sensitive subjects the smallest tube (No. 3, 10 millimetres) should be used. Exceptions must, of course, be made to this general rule in pathological cases, when it is a question of passing a dangerous spot or of penetrating as deeply as possible into a narrow stenosis. It is advisable for beginners, when introducing the spatula-tube without a mandrin, to employ the small sizes.

In all cases where a tumour is suspected, the double curette fixed at a suitable length should always be held in readiness. In the case of foreign bodies the surgeon ought, if possible, to have two forceps of different lengths, as he should always be prepared to find that the foreign body has changed its place. It is, therefore, especially desirable that an assistant should know how to alter the length of the forceps, or at least be accustomed to change the end-pieces.

2. Preliminary Examination of Patients.

Every introduction of the tube must be preceded not only by an exact and exhaustive preliminary examination of the œsophageal affection, but also by a thorough general examination with a special view to any contra-indications to œsophagoscopy.

The past history of the complaint, a careful inquiry into the character of altered deglutition and its gradual progress and persistence, the nature of any vomiting that may occur, or of alleged bleeding, and also the observation of nervous and psychic elements, can all afford valuable indications for future examination. When any doubt is present, such examination should always begin with an objective examination of the swallowing-power, of the manner of eating and chewing, and if possible with an examination of the power of chewing, using Killian's chewing-cup. Some defect of the teeth, overlooked on mere inspection, or the habit of fast eating, or other circumstances having an important bearing on subjective or objective disturbances are then often discovered. The general preliminary examination may be completed by an inspection and functional testing of the pharynx (paralyses and impaired sensibility), and possibly by auscultation of the sound in swallowing (which is, however, of doubtful use in diagnosis).

A laryngologist must in all doubtful cases try indirect laryngoscopy and tracheoscopy before introducing the tube. This makes it possible, not only to discover paralyses of the vocal cords, deformities or displacement of the larynx, compressions, inflammations and malformations of the trachea, which may cast a direct light on the nature of the œsophageal affection, but also frequently reveals some obstacle to deglutition in the upper œsophagus (tumours, foreign bodies, scar stenoses) which is a contra-indication to the blind introduction of a tube with a mandrin. The mere accumulation of mucus or fragments of food in the sinus pyriformis should cause stenosis of the hypopharynx to be suspected, and is a warning that this dangerous region must be cautiously handled. This is a case where it may be advisable to employ von Eicken's method of indirect hypopharyngoscopy, which frequently renders direct examination unnecessary or at all events affords important indications for the mode of procedure.

In addition to the laryngoscopic examination, the surgeon ought not to forget carefully to inspect and palpate the neck, in order to ascertain its mobility. In some cases the use of Röntgen rays (aneurism) with a bismuth meal (pareses, stenoses) or a skiagram may be advisable. If the presence of foreign bodies is suspected, a plate with negative results is not of much importance, as in the thoracic part of the œsophagus, even specifically dense bodies (needles, bones, and heavy glass) may, if small, be lost in the strong mediastinal shadow. Positive results are of great value, not only for topographical location, but still more for enabling the size, position, and shape of the object to be extracted to be ascertained exactly.

A very important part of the preliminary examination is to decide whether a bougie should be passed for diagnostic purposes. When an opinion has been formed as to what the bougie may accomplish, three types of case in which it may be useful can be distinguished—(1) To ascertain the presence of a foreign body or of a stenosis; (2) to ascertain the degree of stenosis; and (3) the topographic location. The value of the bougie as bearing on œsophagoscopy is very different in the three cases.

If there is a doubt as to whether any stenosis exists, and whether it is anatomical or spastic, there is certainly no reason why a thick olive-ended bougie should not be cautiously introduced, provided the obstruction is not situated at the mouth of the œsophagus. In this way the patient may not only frequently be spared the unpleasant experience of œsophagoscopy, but may be convinced in many cases that his impression of the presence of an obstacle to swallowing or of the existence of a foreign body, is purely subjective. In the case of carcinoma, which is by far the most frequent cause of stenosis of the œsophagus, it must be borne in mind that the passing of a bougie may easily occasion slight bleeding, which renders ocular observation very difficult. Therefore, if a carcinoma is suspected, the surgeon should proceed very cautiously, and a bougie should, if possible, not be passed immediately before endoscopy.

In cases where the presence of foreign bodies is suspected, the question of bougies is rather different. The use of a bougie with a negative result does not justify the assumption that no foreign body is present, because even thick olive-ended bougies may slip past large foreign bodies. Gottstein mentions quite a number of such cases in which even a practised hand failed to detect large sets of teeth, probably because the bougie, in its tendency to straighten itself, slips along the posterior wall of the œsophagus, or finds an unimpeded passage in a lateral pocket. An error in diagnosis, owing to such an occurrence, may be fatal for the patient, and has, indeed, frequently been so. It may also be remarked that foreign bodies are not infrequently carried down by the slightest touch of the bougie—even the reflex peristalsis will suffice—and that the presence of foreign bodies in the lower parts of the œsophagus is by no means free from danger.

For this reason I refrain from using the bougie when there is a probability of a foreign body being present. If there is only a slight suspicion, and if the nature of the object swallowed, the time that has elapsed, and the subsequent swallowing of nourishment would seem to preclude the presence of the foreign body in the œsophagus, the patient may be reassured by passing a bougie, and œsophagoscopy may for the moment be dispensed with. It must, however, always be borne in mind in such cases that the bougie is unreliable, and the well-known fact must be remembered that large foreign bodies may be lodged in the gullet for a long time without causing inconvenience, whilst a slight injury or a small patch of inflammation may for days together cause an intense feeling that a foreign body is present.

The second result of exploration with a bougie is to ascertain the width of a stenosis, but this is rather unimportant as an indication for œsophagoscopy. It should therefore be delayed until after the diagnosis with the eye.

The third object attained by the bougie—*i.e.*, ascertaining the position of the obstruction—is considered by most authors to be very important, because when using previous œsophagoscopes an indication is afforded for the selection of a tube of suitable length. The extensible tube is of great advantage here, not only in rendering the unpleasant experience of a bougie unnecessary, but also in making it possible always to work with the length of tube most suitable to the varying height of the foreign body. The advantages of this arrangement are particularly obvious in the extraction of foreign bodies, as they may be followed with the internal tube when, as is so often the case, they recede downwards.

Gottstein is strongly against the introduction of the tube in cases of affections located in the upper part without the previous passage of a bougie, because the physiological resistances at the mouth of the œsophagus render impossible the requisite delicate manipulation of a tube armed with a mandrin. It will be seen later on that with my œsophagoscope even these indications for a bougie are superfluous, because, if the presence of disease in the cervical portion is suspected, the open tube spatula under the direct control of the eye is always used.

It will be seen, even from this somewhat summary account, that the classical method of exploring the œsophagus with the bougie is of only relative importance for determining indications and preparing for œsophagoscopy, and that it can never be a substitute for direct inspection. I will, however, allow that it has the advantage of preparing the subject in some degree for the unpleasant experience of tube introduction, and enabling the surgeon to foresee the difficulties that lie in front of him. If, therefore, none of the above-named difficulties stand in the way, it may certainly be applied with this object when the behaviour of the patient renders it desirable.

One point which is of particular importance in the preparation of the patient is the amount of food present in the stomach. I have already explained in Chapter II. that during the process of digestion the secretion of saliva and mucus, and the irritability of the parts, is much increased. The latter is especially true of the retching reflex, which, if not sufficiently counteracted, is an even greater hindrance to œsophagoscopy than is the glottis reflex to tracheoscopy.

It is therefore advisable, if possible, to carry out the examination when the patient is fasting, and preferably in the morning. It is seldom possible to wash out the stomach previously, as generally stenoses or foreign bodies have to be dealt with. Only in the various forms of œsophageal dilatation is it proper to use douches, and here the main use is to effect a complete cleansing of the œsophagus itself. If it is only a question of excessive mucous secretion, it may be advantageous for the patient to drink some lukewarm Ems, Fachinger or similar water shortly before being examined.

If, as is often the case when foreign bodies are present, examination has to be begun when the stomach is full, the surgeon should be prepared to effect washing with the tube. This is particularly the case with children, whose marked tendency to vomiting is often increased with narcosis.

Special disinfection of the œsophagus or of the mouth is not necessary. For sterilizing the instruments the same rules should be followed as in the case of bronchoscopy.

The above explanations can, of course, only offer a general indication regarding the direction to be taken in special preliminary examinations of œsophagoscopy. In individual cases they have to be supplemented by clinical observation, and in all cases by a general examination, attention being principally given to any contra-indications to the introduction of the tube.

Apart from the acute inflammatory processes of the œsophagus itself and its surroundings, aortic aneurism must be taken as the chief contra-indication. The examination is also dangerous in cases of cirrhosis of the liver, as congestion of the portal circulation caused by the vena coronaria sinistra ventriculi frequently leads to severe extravasation in the lower section of the œsophagus. Uncompensated heart lesions, and especially insufficientia myocardii, require very great care, as also do cases where the respiration is embarrassed (stenoses, phthisis, emphysema), because the mere pressure of the tube on the larynx and trachea, with aspiration of saliva, unaccustomed posture, and all the excitement connected with the operation, may suddenly increase difficulty of breathing to a dangerous degree, or even bring on fatal syncope. Owing to the unavoidable increase of pressure when the head is low, cases with a high degree of arteriosclerosis, especially when there is an apoplectic history, may give rise to some anxiety. In a case of life and death, where a foreign body is firmly impacted, the relative contra-indications to œsophagoscopy must, of course, be overridden. Œsophagotomy for foreign bodies is followed by a mortality of from 12 to 20 per cent.*—*i.e.*, nearly ten times as great as that following œsophagoscopic treatment. Of course this method also has its limits. Thus, if a perforation has occurred, and unmistakable signs of mediastinitis are present—increasing fever, excessive pain, spreading surgical emphysema—it is better to spare the subject the pain of introducing the tube, because in any case œsophagotomy or mediastinotomy are necessary, and a fatal result would be ascribed to the method. The same procedure also holds good after an unsuccessful œsophagoscopy, or after an attempted extraction has failed, if symptoms of perforation should appear. In such cases the threatened danger can only be met by an adequate opening of the mediastinum.

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* Quoted from Starck, "On the Importance of Œsophagoscopy,' etc., *Zeitschr. f. Laryngologie,* Bd. 1, Heft 1.

Unfortunately, in these serious circumstances there is always great uncertainty attached to any plan of operation, and it is largely a matter of personal opinion how long increasing fever and increasing pain should be watched expectantly. It must be admitted that simple œsophagitis, arising from foreign bodies or after their extraction, usually subsides notwithstanding the pain and fever. The rate of progress of the fever, etc., seems to be of more consequence than the actual degree at the moment. Every hour during which there is no change may be taken as a favourable sign; whereas, on the other hand, a steady progress of the fever, etc., will indicate the possibility of mediastinal complications. It is important to notice that œsophageal pain is increased intolerably by the act of swallowing, whereas mediastinitis causes continuous pain with increasing rapidity of respiration.

3. Conditions suitable for Œsophagoscopy.

Œsophagoscopy, when carried out scientifically, is not dangerous, but is always an unpleasant procedure. It appears to me that, generally speaking, it exhausts the subject more than tracheobronchoscopy. For instance, for the latter it is easy to get practised patients for students to examine, but it is difficult to get a subject to submit voluntarily to an examination of the œsophagus, and my class has often to be content with a single preliminary examination with demonstration.

There are, moreover, strongly marked individual differences with regard to the practicability of œsophagoscopy, and these I shall explain, with their reasons, farther on. I only mention the fact here in order to show that, with the direct examination of the œsophagus, it is necessary to be generally more precise with regard to the indications, and take more account of individuality, than is the case in tracheo-bronchoscopy. I do not believe that this view militates against the general appreciation and popularization of the œsophagoscopic method, but rather incline to think that by strict attention to the indications in each individual, and by scientifically reasoned limitation, this method gains both from the surgeon's and the patient's point of view than if it were to be forced, with the ardour of a specialist, upon all cases of œsophageal complaints.

It appears from Gottstein's account that in von Miculicz's clinic œsophagoscopy was practised with discrimination, as is cystoscopy which is naturally not employed in every case of bladder trouble. "The number of cases treated by us with the œsophagoscope," says Gottstein, "is small in proportion to the number of cases of œsophageal complaints. We have not carried out œsophagoscopy even in a third of the cases. In the other two-thirds we had to content ourselves with a diagnosis resting on probability, which in most cases indicated carcinoma."

I need scarcely say that the above remarks are intended to counteract an imperfect appreciation of the scope of œsophageal operations, and are not prompted by an under-estimation of the value of the œsophagoscopic method. If it were only for what it can accomplish in the diagnosis and treatment of foreign bodies which have been swallowed, it is absolutely indispensable. It is scarcely less important in the diagnosis of large dilatations, Zenker's diverticula, and the spastic stenoses underlying these complaints. Among the anatomical stenoses of the œsophagus (scar stenoses, new formations, compressions), the most common one—*i.e.*, carcinoma—ought always to be diagnosed endoscopically when a general clinical examination leaves any doubt whatever, as is very often the case. At all events, the general condition of the patient and his individual suitability for œsophagoscopic treatment will be more likely to be taken into account in this way. Unfortunately, patients suffering from stenosis of the œsophagus sometimes come to the surgeon in such a wretched condition that he is obliged in the first place to perform gastrostomy under local anæsthesia, and later on, when the patient has got stronger, to proceed to endoscopic examination.

If an attempt is made to define what constitutes suitability for œsophagoscopy, as I have done with regard to autoscopy—*i.e.*, the percentage of patients who may and ought to be subjected to direct examination—the question is rather indefinite. The limits depend on the individual views of the surgeon and the varying urgency of indications, whilst there is no available numerical criterion for estimating the degree of inconvenience to the patient such as I was able to establish in the case of endoscopy of the air-passages by measuring exactly the autoscopic pressure of displacement. This pressure affords no criterion for the practicability of examining the œsophagus, and there is no justification for drawing a parallel between the suitability for autoscopy and suitability for œsophagoscopy, or to conclude that when the one method proves easy the other will do likewise.

Kirstein has laid it down* that only persons suited for autoscopy —*i.e.*, about 75 per cent.—are amenable to the introduction of straight tubes into the œsophagus, and that autoscopy affords a direct estimate of the likelihood of œsophagoscopy. This is incorrect for the following reasons:

The presentation of the larynx or trachea requires not only that the upper teeth should be brought into the same line by bending the head back, but it is necessary at the same time for the root of the tongue to be displaced very considerably. It has been seen before that the pressure required for this displacement increases in rapid progression as the posterior wall of the larynx, the vocal cords, and the region of the anterior commissure are successively brought into view. The limits of suitability for autoscopy are therefore included within the region *a*—*b* (Fig. 91), in which I have represented graphically the rise of pressure in the form of a curve.

It is readily seen from the curve that the direction of the tube

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* *Berliner Klinische Wochenschrift*, 1898, p. 594.

c—*d* does not normally fit into the autoscopic pressure curve, but in any case remains at a distance from that point between *a* and *b* up to which individual autoscopy reaches. Œsophagoscopy only requires a straight line between the upper row of teeth and the hypopharynx, whereas complete autoscopy requires a straight line from the upper row of teeth to the anterior commissure. Between the two there is an angle of about 15°, which can never be compensated by stretching the head.

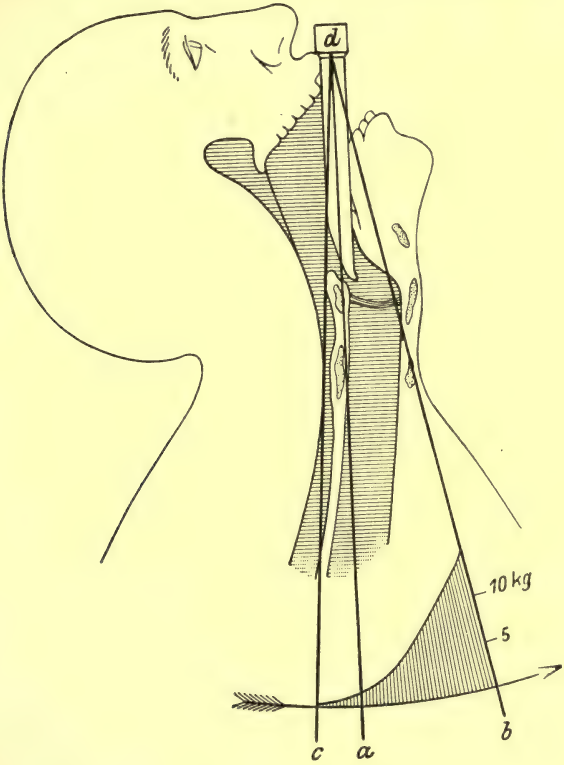

FIG. 91.

These totally different mechanical conditions show how suitability for autoscopy and suitability for œsophagoscopy are independent, and indicate at the same time the essential difference of technique between the two methods of examination. As the introduction of a straight tube into the œsophagus is easy in proportion as the upper row of teeth can be brought into a direct line with it, the examination will frequently, or rather generally, be conducted from the corner of the mouth. In direct laryngoscopy, on the other hand, the tube must in the first place be directed to the point where the tongue can be most effectively displaced, and this point, as I have shown before, is situated more towards the middle than towards its lateral attachments.

If the mechanical difficulties in the way of œsophagoscopy are to be enumerated, mention must be made in the first place of the imperfect mobility of the short cervical column, especially in its upper part. The flexion of the lower part of the cervical column can be of little use in straightening, as appears from Fig. 91, as the cervical part of the œsophagus follows the curve. Great prominence of the upper jaw or upper row of teeth will, of course, act in the same manner as shortness and rigidity of the vertebral column. In the third place there is rigid anatomical fixation of the mouth of the œsophagus, and increased irritability with spastic contraction, to which is frequently added the imperfect effect of local anæsthesia in abolishing reflexes. The degree of development and plasticity of the root of the tongue has no important bearing on œsophagoscopy.

Consequently it is clear that the criteria for autoscopic suitability only partly coincide with those for œsophagoscopic suitability, and that the "tongue spatula test," which is so very important in the forecast for direct laryngoscopy, does not afford any certain criterion with regard to the practicability of œsophagoscopy. All that is possible, then, is, in the main, an examination of cervical mobility, dental development or prominence of the upper jaw, irritability, psychical constitution, and the use of the bougie—which is often contra-indicated. It is also useful to notice the patient's behaviour during the application of cocaine. It may be taken as a rule that examination is easier in the case of thin long-necked people, women, children, and old people (provided their cervical column has not grown stiff), than it is in the case of muscular and well-nourished men.

Apart from morphia injection and general anæsthesia, there are, unfortunately, few expedients for facilitating the introduction of a tube in the case of subjects who are not suitable for œsophagoscopy, because a procedure analogous to counter-pressure autoscopy cannot be applied. It is necessary therefore to use specially thin tubes, since every millimetre makes examination more tolerable. The fault is not that the mouth of the œsophagus is too narrow, but that its connection with the vertebral column is too short. The lower end of the tube can only move backwards to a very limited extent, and consequently the entire unavoidable pressure on the upper jaw is felt as a painful drag at the mouth of the œsophagus. That such a drag is not felt in tracheoscopy is easily explained. In the first place, the œsophagus is situated behind the trachea and consequently the distance from the upper row of teeth to the hypopharynx is longer than that to the larynx; this has the same bearing on straightening as a very prominent upper jaw. Moreover, its connection with the vertebral column is considerably shorter, and, also, in tracheoscopy the strongly compressed root of the tongue offers a strong resistance to the forward drag.

As, in straightening the passage, it is only necessary to save space in a sagittal direction, a tube with an oval cross-section would theoretically be of great advantage. Practically, however, such an advantage seldom occurs, because during ordinary examination a rotary movement of the tube is often necessary, and the oval shape is a disadvantage when the instrument is introduced at the corner of the mouth. The medial method of examination is principally applied when there is a gap in the front teeth, and the breadth of this gap can often only be utilized with a round tube. The fact that two flexible stomach-tubes are able to pass the orifice of the œsophagus side by side is no criterion for the introduction of rigid tubes.

In practice it very seldom happens that the introduction of a tube entirely fails owing to unfavourable conditions for œsophagoscopy. Gottstein found only three such subjects among his very numerous patients, but I suspect that many a difficult case was to be found among those patients (two-thirds of the entire number) who were at the outset excluded from examination. I should like to repeat that I wish to distinguish between suitability for œsophagoscopy in general and the practicability of the method. Its practical importance rather consists in observing a correct proportion in each case between the troublesomeness of the examination and the advantages to be expected from it, and in not losing sight of the limits within which general anæsthesia should be resorted to, since the mechanical nature of the obstruction in difficult œsophagoscopy shows that it cannot be overcome to any appreciable extent by mere anæsthesia of the mucous membrane.

This may be the place to say a few words on the dangers of the direct examination of the œsophagus. As far as the method itself is concerned, these dangers are very slight, as perforations may be avoided with the same certainty as in tracheo-bronchoscopy. Danger from infection or cocaine is nearly absent, as are also any possible complications which may arise when examining the air-passages, such as obstruction of breathing and lung affections.

Cases of death during œsophagoscopy were always found to be directly connected with pathological changes, more especially carcinoma and dangerous foreign bodies. In cases of carcinoma of the mouth of the œsophagus, even the skilled hand of von Miculicz twice made a perforation with fatal results. Von Hacker, Karewski, Rosenheim, and others, have had to deplore fatal results in connection with œsophagoscopy. But all these unfortunate cases, generally due to very special circumstances, are so rare, compared with the thousands of successful examinations, that they in no wise invalidate the method. Besides, some of them took place when œsophagoscopy was in its infancy, and some may be ascribed to faulty technique. Of this latter I shall have to speak at greater length in the following section.

C. TECHNIQUE OF EXAMINATION.

Introduction.

In contradistinction to what applies to the air-passages, the ocular examination of the œsophagus can only be carried out by employing dilating specula which cause the closed cervical section to gape. If such a speculum is introduced so far that its upper end lies in the pharynx, the illumination and inspection will have to be indirect — *e.g.*, with the help of a laryngeal mirror. This is called "indirect œsophagoscopy." If, on the other hand, while displacing the root of the tongue and stretching the cervical vertebral column, the (tubular) speculum is allowed to project from the mouth, it is possible to obtain direct illumination and inspection. The latter procedure is the only one of practical importance, and consequently the term "œsophagoscopy" is always understood to imply the direct method.

A strict division, on the lines of those terms which have been introduced in connection with endoscopy, would have to distinguish between upper and lower œsophagoscopy, because, of course, ocular examination is possible from the wound caused by œsophagotomy. The practical importance, however, of the lower method is considerably smaller with regard to the œsophagus than with regard to the air-passages, and that for obvious reasons. Consequently, it seems hardly necessary to adopt a special term. It will be necessary to speak later on of "retrograde œsophagoscopy," by which is meant the inspection of the œsophagus which is occasionally practised from the stomach when opened in operation.

In giving an account of the special method of examination, I have treated the introduction of the tube separately from the subsequent course of examination, in order to emphasize the peculiar importance of the various methods of introduction, as this does not generally receive adequate recognition. At the end of the section will be found a synopsis which is intended to afford a general survey.

I begin with anæsthesia, which can hardly be separated from the special procedure of examination, after which I shall proceed to discuss, in logical sequence, the various positions in which examination may be effected.

1. Anæsthesia.

The question of anæsthesia presented the greatest difficulty to von Miculicz at the beginning of his œsophagoscopic researches. It was found impossible to push inhalation anæsthesia far enough, without danger, to suppress the swallowing and vomiting reflexes; and as these were intensified when the subject was only lightly anæsthetized, he endeavoured to substitute morphia injections, and so gave the patient 0·04 gramme of hydrochlorate solution ten minutes before the introduction of the tube. This not only produced an effective absence of reflexes, but, as the subject retained consciousness, he was able to call out when the pressure became too great. Von Miculicz must, however, have experienced some serious consequences when using such large doses of morphia, and he soon gave up the practice. In 1887 he adopted the method introduced by Störk and von Hacker of cocainizing the pharyngeal funnel.

This cocaine anæsthesia, by means of which œsophagoscopy was able to be generally and comparatively safely used, has been modified in various ways by different authors. Von Hacker himself attached little importance to an extensive application, whilst Gottstein goes so far as to apply a 10 per cent. solution to the root of the tongue, the hard and soft palate, the back wall of the pharynx, the epiglottis, the sinus pyriformis, the arytenoids and aryteno-epiglottidean folds, and also introduces the swab as far into the œsophagus as possible. Rosenheim even injected a diluted solution of cocaine into the œsophagus by means of a special syringe.

I consider that such an extensive application of cocaine is both troublesome to the subject and just as unsuitable as it is to practise œsophagoscopy without any anæsthesia whatever, as is occasionally advised. In case of necessity, it is possible to introduce a tube in the same manner as a bougie into the œsophagus without previous cocainization, but only in the most tolerant subject could a clear field of vision be expected. It must not be considered by any means the rule that the proper application of cocaine troubles the subject more than the introduction of the tube.

The best procedure in œsophagoscopy will be attained if a careful distinction is made between the suppression of existing reflexes, of pain, and of psychical reactions. As a general rule, reflex and surface pain should be treated exclusively by means of local anæsthesia, psychical reaction and deep-seated pain exclusively by means of general anæsthesia, and combinations of the two by simultaneous general and local anæsthesia.

LOCAL ANÆSTHESIA.

Local anæsthesia in œsophagoscopy is, on the whole, much simpler than in the case of the air-passages, as hindering reflexes only play a small part. As a rule the application of a 20 per cent. solution of cocaine with the addition of adrenalin may be limited to the posterior wall of the pharynx just above the entrance to the œsophagus, to the hypopharynx and the uppermost part of the œsophagus. It is scarcely necessary to use the painting syringe, owing to the slight amount of cocaine applied, and it is possible to manage quite well with two or three roughened laryngeal probes, to which medium-sized woollen swabs are attached. For a more complete anæsthesia of the œsophagus, as, for example, in the neighbourhood of foreign bodies, I would recommend the painting syringe. If a straight end-piece is used, it can be applied with the tube spatula under the direct control of the eye.

It is possible to paint the mouth of the œsophagus by feel, but it is more satisfactory to do it with the help of the laryngeal mirror. The swab is introduced into the sinus pyriformis, and, by moving from left to right, the slit-like hypopharynx can be painted, as can, also, the posterior wall of the pharynx. With regard to the amount used, the varying irritability of different individuals should be taken carefully into account.

It is advisable to wait at least one minute after the first rapid application, because the second application can then often be borne with little inconvenience, and the swab may be introduced into the mouth of the œsophagus if a little pressure is used and the patient asked to swallow. In cases of great irritability it may be necessary to resort to a third or even a fourth application, in the event of the second or third one not being borne after a short interval without reflex.

It reassures the patient very much if, before the application of cocaine, its object and the accompanying inconveniences, such as unpleasant taste, sensation of swelling, and impeded swallowing, are explained. He must be told to spit out at once any cocaine which has got into his mouth.

This cocainization is sufficient in the majority of cases. At any rate, it serves for the introduction of a tube and mandrin by feel, as with proper manipulation the hard palate, velum, etc., are not touched ; and if the usual method from the corner of the mouth is adopted, the epiglottis is also avoided. The lateral part of the tongue is usually not very sensitive to firm pressure, so that it is generally unnecessary to paint it. In the case, however, of ocular introduction of a tube spatula, without a mandrin, it is necessary, or at least desirable, to apply cocaine to the laryngeal surface of the epiglottis and to the root of the tongue, as these have always to be touched, in medial introduction, for the purpose of autoscopic orientation (see below). A single application of cocaine to the mouth of the œsophagus has a greater effect than is the case in the larynx, and for the purpose of œsophagoscopy it is quite sufficient. No disturbing reflexes arise from the deeper parts of the œsophagus, and the manipulation of both tube and instruments is usually quite painless. Cramp-like reflexes due to injury or inflammation can be abolished by means of cocaine.

GENERAL ANÆSTHESIA.

The surgeon cannot be warned too strongly against endeavouring to remove reflex or other more or less clearly recognized hindrances to introduction by means of general anæsthesia. The only indication for its use is real unavoidable pain or excessive psychical reaction, when all expedients, such as reasoning and encouragement or systematic preparation, have proved unavailing. No doubt œsophagoscopy may in rare cases cause a dragging pain at the orifice of the œsophagus, even when thin tubes are used, and for this local anæsthesia alone is no adequate remedy. If, in addition, the patient is in a state of nervous tension, etc., the limit of what he should be called upon to endure is nearly reached, and it becomes necessary to consider the advisability of other means of anæsthesia. Whether these measures are resorted to or not will depend on the various views taken by physicians and surgeons, but they must in any case have regard to contra-indications and the personal wishes of the patient.

It will often be advisable to use morphia injections when hesitating between local and general anæsthesia. A dose of 0·015 gramme, or in the case of strong men 0·02 to 0·03 gramme, administered fifteen minutes before the tube is introduced, will so far increase endurance that even timid subjects will get over their dread of the tube. The harmlessness of a single injection of morphia as compared with a general anæsthetic, and its quieting effect (when supported by suitable suggestions), justify the adoption of this means in a large number of cases of direct examination. That the dazed condition induced by morphia and scopolamine is unsuitable for œsophagoscopic purposes has been shown at length in Chapter II.

In Killian's clinic general anæsthesia is seldom resorted to in the case of adults (compare statistics on p. 76). In the case of children, at the age when they cannot be expected to keep quiet or cannot be forced to do so, general anæsthesia is always required in order to attain the stillness necessary for precision in difficult œsophagoscopic work. The anæsthesia must be deep enough to abolish all straining movements, whilst the reflexes at the mouth of the œsophagus must be controlled by the use of cocaine when the patient is under the anæsthetic.

The method of administering the anæsthetic until the tube is introduced (see Chapter II.) is the same as is usually practised.

Afterwards it is sufficient to hold a pad saturated with chloroform in front of the mouth.

2. Position of the Patient.

The various lying and sitting positions of the subject have a somewhat different bearing in œsophagoscopy than is the case in the direct examination of the air-passages. Whereas in the latter the position is chosen mainly with reference to the difficulties of introduction—orientation, autoscopic displacement—in examinations of the œsophagus the chief aim is to avoid interference by the saliva.

The introduction of a tube into the œsophagus always causes increased salivation and increased flow from the œsophageal mucous glands. If the examination is carried out in a sitting position, the secretion is constantly trickling to the lowest part of the œsophagus, and so accumulates in the fields of vision and necessitates repeated cleansing. Still more unpleasant are the occasional interruptions caused by the accumulation of saliva in the mouth. Not every subject is able to swallow or to spit out while the tube is in position; consequently, when salivation is excessive, the saliva runs into the trachea and causes an irresistible inclination to cough, and this is not usually controlled even by swabbing or pumping the saliva from the mouth.

Accordingly, œsophagoscopy in a sitting posture should only be employed for brief examinations and operations, and especially for the ocular introduction of the tube (without a mandrin). It offers one essential advantage in that it allows the surgeon to introduce the tube more readily and to carry out operations in a more comfortable position both for himself and the patient. For the patient the upright position is decidedly less unpleasant, as it allows him greater liberty of movement, and the whole procedure appears less alarming than when carried out on an ominous-looking operation-table. It must also be remembered that elderly and corpulent persons often experience great discomfort when lying on their backs with their heads hanging over the end of the table, more especially as their shortness of breath is always intensified by the introduction of the tube.

The advantage of the free drainage of the saliva in the lying position is at once apparent in cases of excessive salivation, and this position should always be adopted for prolonged examinations (over five to ten minutes). This position is absolutely the right one in all cases in which the necessity for a thorough cleansing of the œsophagus (spasm with dilatation, stenosis, or foreign bodies when the stomach is loaded) is anticipated. It need scarcely be mentioned that œsophagoscopy in feeble subjects or children can only be carried out on the table.

The greater number of surgeons examine exclusively, or at least mainly, in the lying position, and this may be explained by the fact that so far the introduction of the tube by feel is still generally practised. I am convinced that the great practical importance of the ocular method (without a mandrin), as rendered possible by the use of my extensible œsophagoscope, will lead to a more frequent use of the sitting position. In Killian's clinic this was adopted long ago, as the introduction of the open tube with the patient sitting is far easier both for œsophagoscopy and tracheoscopy than when the patient is lying down.

Von Hacker and Rosenheim have proposed a special procedure which involves a change of posture. The patient sits on the operating-table in such a way that, when he lies down, his head will project beyond the end of the table. The tube is then introduced by the operator, who stands on a footstool, after which the patient is carefully moved into a lying position. This procedure, though by no means without risk, seeks to combine the advantages of the easier introduction while sitting with those of the lying position. Personally I have never been tempted to try this complicated manœuvre.

As regards the several positions, the same remarks apply here to the sitting posture as in the tracheoscopy. The patient is made to sit on a stool without a back, 25 to 30 centimetres in height; an assistant, standing behind him, supports his head, which is bent backwards, keeps it in the right position, and carries out the operator's directions regarding movements and changes of position.

The essential points that should be aimed at in constructing a special table have already been mentioned. It is especially important that its height should be such as to make it easy for the operator, when seated, to look into the tube.

There has been much discussion as to whether examination can be better effected when the patient is lying on his back or on his side. I give the preference generally to lying on the left side, because the surgeon then occupies the same position towards the subject as in œsophagoscopy in a sitting position, and because the tube can then be introduced with the right hand in a natural way (compare Fig. 72, p. 200). The lateral position appears to me to be also advantageous for prolonged examination, because the saliva can escape unhindered; whilst it allows free play of the vertebral column in the sagittal direction, if the legs are drawn up, and adequate relaxation of the muscles of the neck and trunk. Experience further teaches that the lateral position is less trying for the patient during long examinations than the dorsal position, with the head hanging over the end of the table. When the lateral position is adopted, the tube should be introduced from the lower corner of the mouth, so that its outer end be as low as possible—unless a gap in the middle of the teeth indicates the medial position. If the upper back teeth on the right side are the only ones that are absent, the position on the right side must be preferred, on account of getting rid of secretions.

The dorsal position is especially indicated if it is intended to to introduce a tube into the stomach. Of the lying positions, that on the right side is best calculated to equalize the lateral curve of the abdominal portion of the œsophagus; but the straightening of the ventral curve by complete extension of the vertebral column is here more important, because the œsophagus is sufficiently mobile in the frontal plane. In the dorsal position (even during anæsthesia) it should be seen that the knees are slightly drawn up, so that the lordosis of the lumbar column is equalized and the muscles of the abdomen relaxed. With due care the subject may also be turned from the lateral to the dorsal position after the tube is introduced.

It is of great importance to make the patient's position as comfortable and unconstrained as possible, so that he may continue in it for a considerable time without undue tension of the muscles. Of course he should be free from incommoding articles of dress, and his head, which projects beyond the end of the table, should be firmly but not rigidly supported. When the patient lies on his side, the assistant should be at his back; and when he is on his back, the assistant should be on the right of the operator, or, still better, sitting on a low stool. Sand-bags and pillows are unnecessary and can in no case render the presence of an assistant superfluous. When the examination is conducted in the lying position, it is scarcely possible to do without a second assistant to look after the saliva-pump. Before undertaking an operation, the surgeon ought to make sure that the assistant is also perfectly familiar with the manipulation of the forceps.

3. Methods of Introduction.

Whereas in direct examination of the air-passages the primitive introduction by feel, with a mandrin, will soon be superseded by the ocular method, in œsophagoscopy the use of the bougie is as yet predominant. The reason for this is mainly that the passing of a bougie into the œsophagus has been traditional for many years, while it is also dependent on the nature of œsophagoscopy as hitherto practised, and the insufficient autoscopic experience of many œsophagoscopists. Another reason is that ocular introduction requires a little more practice, and if not done skilfully is more troublesome to the patient. Nevertheless it must be learnt, because an œsophagoscopic method which depends merely upon the introduction of closed tubes is most imperfect. I therefore consider it necessary to discuss the two methods independently.

INTRODUCTION BY FEEL.

Attempts to improve œsophagoscopic technique have always been directed to the manner of introduction, and scarcely a year passes without a new mandrin being invented. If Kelling's procedure is put aside, which is dependent on the introduction of a jointed flexible metal tube which can be straightened afterwards, all the modifications may be divided into two main groups. In the one a rigid or flexible mandrin serves as the conductor, in the other a pliable tube is first introduced and the straight œsophagoscopic tube is passed through it. In both cases it is possible to introduce tube and conductor either together or one after the other, and so a considerable number of methods exist to satisfy individual tastes.

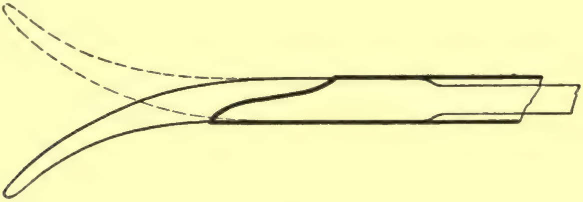

FIG. 92.

If the method of introducing the tube is considered, it is seen that there are two main problems to be solved—viz., the dilatation of the contracted mouth of the œsophagus, and the straightening of the passage. It appears advisable to consider these as separate in point of time—that is to say, the dilatation must first be effected by means of a bougie, and the straightening then brought about by the advance of the rigid tube. When using the rigid obturators of von Miculicz's and von Hacker's œsophagoscope, this separation in point of time is not possible, for which reason I give the preference to the elastic English bougies as tube mandrin.

I have constructed these bougies for the spatula-tube of my œsophagoscope, so that their end is flattened antero-posteriorly like a chisel (Fig. 92). Thus they conform to the natural shape of the œsophageal orifice, and, while they are sufficiently firm laterally, they have a well-graduated dorso-ventral flexibility, so that it is easy to keep them in the middle line. The direction of the flattening must coincide with that of the sloping end of the tube (Fig. 92), and the instrument must not be introduced in the position indicated by the dotted line. The sloping end of the tube, when the bougie fits, offers the advantage that the increase in thickness is gradual and that the mandrin need only project a few centimetres beyond the end.

The introduction of this instrument is so easily managed by anyone who has used a pharyngeal bougie that a brief description will suffice. I will assume that the subject is in a sitting position —the position most advisable in first attempts.

After the illuminating apparatus has been placed exactly right for the medium tube (12 millimetres), it is taken off and the tube fitted with a mandrin. The tube should then be thoroughly smeared with liquid paraffin, oil, or liquid gum, and then be slightly warmed over a spirit-lamp. The patient (who should be free from tight clothing round the neck) should be directed to continue breathing lightly throughout the whole proceedings, to avoid all muscular tension, and to indicate serious inconvenience by lifting his hand, since he cannot speak when the tube is introduced.

The tube is then taken hold of like a pen by the upper funnel-end, with the right hand at the same time holding the mandrin above the knob so as to prevent it slipping back. During the introduction the patient need only raise his head slightly, as much stretching constricts the œsophageal orifice. I consider the introduction of the finger into the pharynx, advancing the larynx, and similar proceedings suggested by various authors, not only unnecessary, but injurious, as they augment reflex resistances. It is quite sufficient to allow the bougie to slide along the posterior pharyngeal wall, and to keep near to the middle line. Even if the end should stray into a sinus pyriformis, in consequence of lateral deviation, it readily regains the middle line when the patient is told to swallow. It often happens that the tonic contraction of the œsophageal orifice is so increased by the advancing bougie as to arouse suspicion that the bougie is passing in the wrong direction. In such a case all violence should be avoided, and the right passage should be sought by probing and lateral movements of the outer end of the tube, while the patient should continue breathing calmly, and swallow when told, whereupon the bougie often passes the œsophageal orifice with a slight jerk. If these devices fail, it is necessary to wait, as the reflex cramp always yields after a minute or two.

It is possible to judge when the bougie has passed the entrance to the œsophagus either by the sudden cessation of resistance or by the fact that the spatula-tube almost disappears into the mouth. When this passage is accomplished, the second act, or straightening, can take place. The patient bends his head farther back, the tube is placed upright in a gap between the teeth, if such exist, or, if the upper jaw is very prominent, into a corner of the mouth, the head being rotated to the other side. The surgeon rotates the tube gently, at the same time maintaining a moderate but steady downward pressure, and can feel a perceptible jerk when the sloping end of the tube overcomes any resistance.

If, after persistent attempts, insuperable difficulties remain, the position of the patient and the direction of the tube must first be seen to. The fault often lies in the head being too strongly extended, especially if the muscles of the neck are kept rigid and the patient holds his breath. He should therefore be required to hold himself slack, and trust his head entirely to the assistant so that he can readily move it in the proper direction. If the object is not attained by these means, it may be (especially in men with thick short necks) that the case is particularly unsuitable for œsophagoscopy, and that the use of a still thinner tube is required.

In the great majority of cases, by following these directions, even a beginner has no difficulty in introduction. A practised hand can do it almost mechanically, and when he knows his bearings can use a little extra pressure as lesions are seldom caused with a well-fitting mandrin.

The tube spatula keeps in position of itself as soon as its lower end is from 4 to 5 centimetres past the œsophageal orifice. The mandrin must therefore only be removed when the 22-centimetre tube projects beyond the upper row of teeth by one or two fingers' breadth. The withdrawal of the mandrin is effected by a rotatory movement, the tube being held fast and slightly depressed. The electroscope is then attached, and ocular examination can begin.

Introduction in the lying position, which is more difficult, must be effected on the same lines. The beginner should always choose the left lateral, as the manipulation and movements in that position most nearly correspond to examination in a sitting posture.

OCULAR INTRODUCTION.

Considering the practical importance of the method of introduction without a mandrin and the small attention which it has hitherto received, I think it advisable to dwell somewhat longer on the indications for it. This procedure, which is somewhat more difficult to carry out, is not intended to replace the introduction with a mandrin in every case, but only when the latter involves direct dangers or fails to accomplish the object of œsophagoscopy. I will now quote some passages from my article on "The Progress of Œsophagoscopic Treatment of Foreign Bodies which have been swallowed" (*Deutsche Mediz. Wochenschrift*, November 17, 1909):

> "The various methods of introduction of a tube armed with a mandrin have this in common, that the most important section of the œsophagus is concealed from view, and the chief rule of endoscopy, that the eye should always guide the hand, is abandoned. These methods are, therefore, only justified when blind groping in the œsophagus is unobjectionable, or when ocular introduction is impossible. It will be seen that neither of these eventualities ever arises.
>
> "Every observer is aware that swallowed foreign bodies, in most cases, remain in the upper portion of the œsophagus near its mouth. Anything which has safely traversed this narrow strait, whose sentinel is armed with the power of reflex contraction, rarely finds any further obstacle in the lower tracts of the œsophagus. The exceptions are long pointed objects, which sometimes stick transversely. For the rest, it may be taken as a rule that, when objects are arrested lower down, it is in consequence of some artificial interference, especially the use of an œsophageal probang, with which objects

of such size and shape are pushed down that they stick even in the widest sections of the œsophagus.

"Burger has lately published some statistics* which bear out this very general experience. Taking 135 cases of foreign bodies which were satisfactorily examined radiographically, he found that more than 90 per cent. occurred in the upper half of the œsophagus. In the cervical section the frequency increases so much that, according to his graphic representation, more than 60 per cent. were arrested above the upper edge of the manubrium sterni. Unfortunately, Burger did not mention whether any artificial manipulation had taken place previous to the radiographic examination, and, as this is very probable, I think it may be assumed that the original percentage of foreign bodies in this upper section is still greater.

"In this connection the question arises whether it is fitting to use a blind tube with more than 60 per cent. of the foreign objects in the œsophagus, and whether the mandrin does not here play the dangerous part of a pharyngeal probang. If it is remembered that the tube must itself be passed considerably beyond the cricoid constriction (*i.e.*, the most usual point of arrest for foreign bodies), if it is not to slip or be forced out when the mandrin is withdrawn, and that the conical bougies serving for introduction usually pass from 5 to 15 centimetres beyond the tube, it is obvious that the foreign body is usually pushed downwards or sidewards before the surgeon can see it. If to this is added the consideration that the introduction of a straight thick tube, even when the best conductors are used, still requires so much pressure that the more delicate feeling of resistance is interfered with, and that at the œsophageal orifice, in particular, normal obstacles to introduction occur, the nature of which may be easily mistaken (spasm), it must be admitted that blind introduction is far from safe in the hands of any but the most experienced.

"These scruples are not new. They were mentioned years ago by von Eicken† in a comprehensive report on the clinical results of the direct examinations carried out in Killian's clinic. He was struck by the fact that in a great proportion of cases, whether treated by himself or others, when the mandrin was withdrawn and the œsophagus was seen with the tube, it was empty, although the patient had previously stated very definitely at what part of the neck he experienced pain from the foreign body. Only in one case was a piece of bone seen disappearing downwards as the tube was withdrawn. It seems natural to assume that, in other fruitless cases of œsophagoscopy, the foreign body was often loosened or simply pushed downwards, and this was confirmed by the further observation that the painful sensations caused by a foreign body were gone immediately after œsophagoscopy. In consequence of this, in the two subsequent cases examination was made with Killian's tube spatula without a mandrin, and on both occasions a foreign body was found and extracted from the typical situation behind the cricoid plate.

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* *Was leisten die Röntgenstrahlen in der Rhino-Laryngologie?* Wiesbaden, 1908.

† *Archiv für Laryngologie*, Bd. 15, Heft 3.

"Observations and interpretations similar to those of von Eicken were also communicated by other experienced œsophagoscopists. If it is considered that many foreign bodies are apt to move down even when cautiously approached with the open tube, and that unsuccessful cases of œsophagoscopy are usually not published, it will scarcely be wrong to assume that, in reality, blind introduction in many cases thwarts the objects of œsophagoscopy, even when it does not expose the patient to serious danger; for it does not follow that objects which are displaced, and so able to pass through the remainder of the œsophagus, are without danger to the intestinal tract. Objects which cannot escape downwards or sideways owing to their size and shape may become a source of danger from perforation through blind introduction, especially as the thick rigid tube can never be manipulated as gently as a thin soft bougie, even by a practised hand.

"It is not my intention to add to the already voluminous casuistry of œsophagoscopic treatment of foreign bodies in the œsophagus, but I should like to mention three cases, treated by myself in Killian's clinic, in illustration of what I have advanced, and which may be considered typical. All three were cases of swallowing large plates of false teeth, two of which had the usual hook-like metal clamps for fastening on to neighbouring teeth. I effected the presentation and extraction with my wide short spatula-tube without a mandrin under the continuous control of the eye. When I applied the forceps, it appeared that the hooks of the tooth-plate were so embedded that it was impossible to move it either up or down without exerting absolute violence. Attempts at rotation likewise met with such resistance that they could only be attempted after exact œsophagoscopic evidence of how the hooks were situated, and so, after having ascertained this, I turned the foreign body in the opposite direction to the hooks—*i.e.*, not towards the points, but away from them. In this way I succeeded in drawing the plate slowly upwards.

"I mention these cases in particular, because sets of teeth are so very frequently swallowed—two of those mentioned were brought in on the same day and from the same town—and because they afford a good example of the danger connected with blind œsophagoscopy. An elastic bougie can easily slip past such an arch-shaped foreign body with irregular projections. Not until the rigid thick tube follows is it pushed down or sideways more or less forcibly. I say more or less forcibly, because the strength required for straightening the passage is such as to preclude the degree of delicate feeling required for the certain avoidance of injury from sharp hooks and the like.

"I think that no further discussion or casuistry is required to prove that the blind introduction of the œsophagoscope, as practised at present, cannot be justified on the score of alleged harmlessness. This is true for most swallowed foreign bodies, and also generally for all obstructions situated in the upper part of the œsophagus, when it would be dangerous to use force; especially is this so, as von Eicken insisted, in the case of malignant tumours at the orifice of the œsophagus. Von Miculicz knew that blind introduction was particularly dangerous in such cases, and, notwithstanding his skill, twice made a perforation. Von Eicken therefore rightly advises the exclusive use of the tube spatula in these cases, as it is not necessary with it to go beyond the tumour, but only as far as its upper end.

"Among rarer affections, I may mention more particularly pressure diverticula as little suited for blind introduction, especially if the pouch is small, with a broad opening into the œsophagus. In one such case I was unable to bring the bulging diverticulum and its œsophageal opening into view even by the use of the open tube spatula. Of course, in such a case the usual procedure of seeking for the passage with the diverticulum probe, and of then pushing the tube over it, was not practicable.

"For such cases my 'window beak-tube' (Fig. 93) for direct operations in the larynx has proved satisfactory. The round-ended, beak-shaped prolongation slides easily through the œsophageal orifice, and it may, if necessary, be turned aside more or less like a diverticulum probe, and thus guided by the eye it can be passed into the excentric lumen of the diverticulum. In this way operations can be carried out at the diverticulum or at the entrance to the œsophagus through the window of the tube.

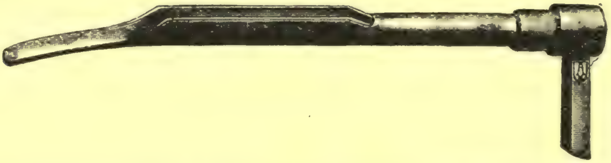

FIG. 93.—BEAKED TUBE WITH WINDOW. (After Brünings.)

"Now that the unsuitability of blind introduction has been shown, the second question is reached—namely, whether this method is a necessary evil, and whether, for want of anything better, it must be acknowledged that it may be justified. I should answer this question affirmatively if only tubes cut straight at the end could be used, which are still in general use, and with which an introduction without a mandrin requires more or less violence, such as forcible pulling forward of the larynx (von Hacker), or a general anæsthetic (Starck). But I cannot say so now, as for several years œsophagoscopy has been practised in Killian's clinic with the open tube spatula, the sloping flat end of which takes the place of the mandrin. Still less can I do so after having constructed my extensible double tube, because it meets further objections—that the manœuvre of introduction has to be repeated in the event of the affection being found to be beyond the reach of the short spatula, or of the foreign body slipping away, or because for some other reasons endoscopy has to be extended to the entire œsophagus."

The importance of purely ocular introduction may now be considered as sufficiently proved. As a matter of fact, the numerous foreign bodies treated in Killian's clinic in later years, and partly by beginners, were, with few exceptions, extracted through the tube spatula of my œsophagoscope without using the inner tube. Only rarely, when the affection is known to be seated low, is the mandrin used. This blind procedure is, I think, contra-indicated in all high-seated affections, or when such are surmised —*i.e.*, in the majority of cases.

As regards the technique of introduction without a mandrin, I will not deny that it requires somewhat more skill than the other procedure, and that in some cases, especially those which are scarcely amenable to œsophagoscopy, it may entirely fail, although personally I have not yet had that experience. In any case it is most advisable for beginners to acquire a certain degree of autoscopic skill, and so overcome difficulties in orientation. For a first attempt it is, moreover, advisable to select a patient accustomed to the passage of the bougie, and with a gap in his teeth, as medial is always easier than lateral introduction. Strict adherence to the middle line is of the utmost importance, as the posterior wall of the pharynx and hypopharynx afford no rallying-points, and the tube is very apt to slip laterally off the convex vertebral column into a sinus pyriformis.

I have found the following procedure the best, and recommend it even for the beginners in my class, provided they are not too clumsy: After a thorough cocainization (which includes the laryngeal surface of the epiglottis and root of the tongue), and with the manipulation described on p. 101, the procedure is exactly the same as in medial autoscopy, and with a moderate degree of extension of the head the interarytenoid region is brought into view. There is here a final opportunity of defining the middle line by ascertaining the centre of the posterior laryngeal wall as it moves on phonation. When this is seen, the end of the spatula is raised somewhat, and passes behind the larynx.

In this way the hypopharynx is reached, that region which is, according to von Hacker, "beyond laryngoscopy and not remote enough for œsophagoscopy." For the sloping tube spatula such a region really does not exist. A moderate pressure with the wedge-shaped end suffices to dilate the hypopharynx into a short transversely-placed fissure, on whose anterior wall the lighter-coloured and often absolutely white surface of the cricoid plate is seen more or less distinctly. It is advisable always to exercise a certain displacing pressure forwards with the end of the tube, until the front cleft of the hypopharynx enters the middle of the field of vision. As the eye always anticipates the tube, the lip of the œsophageal orifice can then frequently be seen projecting from behind, and appearing to present an unconquerable obstacle to further advance.

For overcoming this obstacle the same rules are applied as for the introduction with a mandrin—namely, correct position of the subject, no rigid bending of the neck, relaxed muscles, quiet breathing, and patient waiting for reflex contraction to cease. Swallowing movements are found very helpful, but not all patients can accomplish them in this position. If even moderate increase of pressure does not push the tube past the physiological constriction, some further pressure, which is quite without danger if carefully followed by the eye, is unavoidable, because here dilatation and straightening occur simultaneously. The attainment of a successful result is often aided by the use of rotating movements, the sloping end of the tube then alternately taking a frontal and sagittal position, without, however, departing from the middle line. As soon as any doubts occur, it is better to go back and check the position by the symmetrical phonation movements of the arytenoid cartilages.

The method of introduction without a mandrin appears much more complicated in description than is really the case. In the great majority of cases the œsophageal orifice, when correctly presented, may certainly be expected to open on moderate pressure, and the tube suddenly to disappear without hindrance into the pars cervicalis. The wedge-like effect of the flat end of the tube is scarcely less than that of the blunt obturators of the œsophagoscopes of von Miculicz and von Hacker.

The ocular introduction of the tube is quite possible with the patient lying down, but the sitting position must be regarded as typical, especially when dealing with œsophagoscopy above the bifurcation of the trachea. Children, with whom general anæsthesia has to be employed, should be raised for the actual introduction. If for special reasons the lying position appears necessary, a successful result is best attained by adopting the left lateral position (Fig. 72, p. 200). Lying on the back must in any case be avoided.

4. Course of the Examination.

After the tube spatula has been introduced successfully in one way or the other, the further procedure is usually very simple. The whole passage, from the œsophageal orifice to the entrance of the stomach, is not only free from all obstacles, but continues in such a straight line that no forcible displacements, such as those required in bronchoscopy, are necessary. Indeed, in favourable conditions—*i.e.*, when the slight curves are equalized by specially favourable position—it is possible to see the lumen of the organ for half or even for the whole of its length.

This, however, presupposes a certain depth of introduction, since the cervical section is normally closed for about 5 centimetres below the œsophageal orifice—*i.e.*, forced together by the apposition of neighbouring organs, more especially the trachea—so that its lumen appears as a more or less well-marked transverse cleft. It is not a question of active muscular occlusion, as both the tube and a thick olive may be moved up and down without any difficulty. Accordingly, the gaping mucous membrane funnel produced by the tube descends well in front of it, so that pathological changes, foreign bodies, etc., can always be seen before the end of the tube reaches them. The nearer the approach to the gaping thoracic section, the more easily do the walls move, until finally, at the bottom of the mucous membrane funnel, a lumen is visible on deep inspiration. This rapidly increases in size as the tube is moved on, until, at a depth of 6 to 8 centimetres below the œsophageal orifice, it almost equals the entire width of the pars thoracalis. The length of the tube spatula is so chosen that, when fully introduced, it always reaches down into the gaping thoracic section, so that the œsophagus can be explored at least down to the constriction at the level of the tracheal bifurcation.

A single slow and careful examination is generally sufficient, the rule being observed only to advance the tube as the lumen is exactly presented. Regular deep inspirations on the part of the patient are of great advantage, and have the effect of widening the lumen. This expedient may be used, not only for orientation, but in all operative measures requiring exact vision. The presentation of the wall with a surface view of the mucous membrane requires, of course, lateral displacement. This can be accomplished either entirely with the tube by moving its outer end from one corner of the mouth to the other, or, better, by slowly moving the head. These movements should never be made by the patient, but should always be performed by the assistant. In every case it must be imagined that the movements of the tube are like those of a two-armed lever, the fulcrum of which is on a level with the entrance to the œsophagus. Greater displacements may be necessary when the ends of a transversely-placed foreign body or the lumen of an excentric stenosis are to be presented.

All œsophagoscopic problems below the bifurcation constriction require the application of the extensible tube. As regards its introduction, the holding of the electroscope with sitting or lying patients, the same rules apply as in bronchoscopy, only the greater length of the œsophageal extensible tube makes it desirable to withdraw the spatula tube a little before or during the introduction of the extension tube, so that no part of the œsophagus may be passed without ocular control. Anyone who experiences difficulty in using the watch-spring should first fix the lever, and use the two tubes like a single tube. But this should never be done in order to use more force, as this could only be required as a result of a faulty position or wrong direction of the tube.

After passing the constrictions due to the tracheal bifurcation and to the aorta, whose strong pulsations are tangibly and visibly communicated to the tube, the end of the tube reaches the widest part of the œsophagus, which now gradually curves to reach an extramedian position at the hiatus œsophageus. It is well to be constantly equalizing this curve by pressing the wall to the left, so as never to lose sight of the lumen; and it is further advisable to check the depth of introduction constantly by means of the spring scale, or to have it checked by the assistant. In this way there is a certainty of success in bringing into view the cleft or rosette-shaped image of the diaphragmatic constriction, whereas by simply advancing the tube in a straight line by palpation the end of the tube is sure to catch in the right (lower) wall of the œsophagus.

It is not always easy—indeed, sometimes very difficult—to reach the stomach with the open tube, not only in consequence of the oblique direction of the diaphragmatic canal and the pars abdominalis, but still more because the hiatus is constricted at every respiratory or reflex diaphragmatic contraction by the intercrossing crura. In the endoscopic picture a narrow cleft is seen running from a right posterior to a left anterior position, or else a more rosette-shaped figure. This point should now be exactly defined with the tube, and, indeed, may require a considerable search if any dilatations are present. The tube should now be advanced obliquely by using the right corner of the mouth and moving the patient laterally. Any considerable resistance, apart from those due to pathological changes (spasm, tumours, stenoses), are always due to false direction of the tube, straining of the patient, or unfavourable position. If the straining or cramp results in reflex pain at the cardia, a thorough application of cocaine to this region is often useful. A moderate amount of pressure often leads in time to a successful issue, and this is permissible, but any application of violence is of course to be avoided. This especially applies when there is any suspicion of carcinoma of the cardia.

When the hiatus is passed no more lumen is seen as a rule, because the tube slides into the stomach close along its posterior wall. Frequently, when the tube passes the diaphragm with a jerk, the cardia is passed unobserved, so that a distinct boundary between the mucous membrane of the œsophagus and that of the stomach is not always noticed. Whether the stomach has been reached is shown not only by the absence of resistance and the depth of introduction, but also by the changed appearance of the mucous membrane. The mucosa lining the whole of the œsophagus resembles in texture and colour that on the inner surface of the cheeks, thus markedly differing from the dark violet, velvety glandular epithelium of the fundus. In thin patients the end of the tube can generally be felt, and in a dark room the light may cast a bright glow through the abdominal wall. The passage into the stomach may be easily effected in ordinary cases by using a mandrin of suitable flexibility, such as I use in gastroscopy, but as a rule this procedure does not fulfil the main object of œsophagoscopy.

When withdrawing the œsophagoscope, the whole passage should once more be carefully explored. This applies especially to those parts which are difficult to pass—*i.e.*, the region of the cardia and the cervical section—as these are much more easily observed during a slow withdrawal of the tube. It is best at first only to remove the inner tube, so as to work steadily with the longest field of vision. A porringer should be held in readiness, so that the patient may be able to get rid of accumulations of saliva.

I have intentionally described the routine examination in the foregoing pages without mentioning unavoidable disturbances and difficulties. In reality, examinations are hardly ever so simple, and it is therefore necessary to draw attention to some of the most frequent complications.

In the first place, many patients have a sensation of intense dyspnœa as soon as the tube presses on the larynx, which is very disconcerting. They should therefore be warned previously that such sensations may be expected, and asked to breathe regularly. In case of need the subject should make a sign with his hand, whereupon the tube should be removed, and, after reasoning with him, the introduction may be repeated with greater hope of success. Frequently patients breathe with mechanical regularity, but the voluntary exertion brings all the muscles of the neck into play. Here again both encouragement, explanation, and practice are necessary.

When the tube gets beyond the bifurcation constriction, saliva or mucus are generally encountered, which disturb the field of vision and require the use of the aspiration pump. The pump-tube should be adjusted to the right length, so that the lamp will not have to be moved aside while the liquid is drawn off; it is, however, quite possible, when using wide tubes, to obtain a field of vision by the side of the pump-tube when the lamp is high. It is always necessary in case of foreign bodies or malignant tumours to proceed gently and feel cautiously, so as to avoid displacement or bleeding.

When there is much thick mucus the small hand-pump may prove inadequate. In such a case, if there is no water-jet aspirator (Fig. 3, p. 8), the surgeon must manage with swabs of wool, even though their use often takes up half the time at his disposal. In all cases of increased secretion (chronic affections of the œsophagus) or obstructed outflow (severe stenoses, spasms), the lying position is preferable from the outset, especially if examination has to extend beyond the bifurcation constriction.

Œsophagoscopy in the lying position offers great advantages as regards keeping the field of vision clear, even if the table cannot be depressed sufficiently for the tube, which is in a lower corner of the mouth, to lie in a position sloping downwards. The secretion is much less disturbing when it is spread over the side-wall of the œsophagus, and the pump is much more effective in a horizontal position as the liquid does not require to be raised. Horizontal or sloping positions are essential whenever the œsophagus has to be washed out.

In clearing the field of vision, attention should be paid to the inside of the tube, especially if blood or remains of food are present. A considerable loss of light may be entailed through the interior of a long tube being soiled, and it is often more advisable to clean the tube than to increase the power of the lamp.

There is usually no fear of the field of vision being obscured by peristaltic, respiratory, or pulsatory movements of the œsophagus. I have, however, already mentioned repeatedly that the widening which occurs on inspiration may be advantageously utilized to increase the field of vision. Disturbing factors are the expiratory straining, which occurs in children who are not fully anæsthetized, and the moaning which some patients habitually indulge in all through the examination.

The disturbances which are sometimes occasioned in the sitting position, owing to saliva collecting in the mouth or entrance of the larynx, have already been dealt with. They cause great inconvenience to the patient, and it is necessary to interrupt the examination unless the secretion can be removed by means of a rubber tube. With a moderate amount of practice the greater number of œsophagoscopic problems may, however, be solved during an introduction lasting from five to ten minutes, and the patient may be induced to persevere if he is regularly informed how the time is going.

Œsophagoscopy normally leaves only a slight feeling of pressure in the pharynx, which may sometimes last till the following day, and it is not usually necessary to adopt liquid food or any special régime. Abrasions of the mucous membrane, such as now and then occur from the extraction of foreign bodies or may arise occasionally when there is much difficulty in introducing the tube spatula without a mandrin, are apt to be rather painful when inflammation supervenes. It is therefore very advisable to paint such places œsophagoscopically with a fairly strong solution of silver nitrate (5 per cent.), and to order cold liquid food for the first twenty-four hours. If there is the slightest suspicion of perforation, strict clinical observation, and possibly early mediastinotomy, are required.

I think it not superfluous to give in conclusion a brief summary of the chief phases of examination.

1. History of the illness, special preliminary examination, amenability to œsophagoscopy (in some cases the use of the bougie), general preliminary examination, state of the stomach, contra-indications.
2. Preparation of instruments, choice of tubes and mandrins, arrangement

of the light, lubrication of tubes, saliva-pump, swabs, proper fixing of operating instruments, directions to assistants, darkening of the room.

3. Preparation of the patient, removal of tight clothing and false teeth, anæsthesia after informing the patient of the object and effects of the procedure, precise instructions as regards behaviour during examination breathing, swallowing), or in the event of more serious inconvenience (pain from pressure, sensation of choking).

4. Typical introduction (a gap in the teeth, corner of the mouth) of the tube spatula with a mandrin (lesion known to be low down), or without a mandrin (suspicion of high-seated affections or foreign bodies), if sitting (brief suprabifurcal œsophagoscopy), or if lying (infrabifurcal examination of longer duration, increased secretion, dilatation).

D. SPECIAL DEVICES.

1. Œsophagoscopy with Air Inflation.

Strauss's proctoscope has attached to it a glass disc similar to that in Siegle's ear speculum, so that the intestine can be inflated with air during investigation. The main object of this procedure is to dilate the collapsed or contracted intestine in order to facilitate the introduction of the tube, especially in situations where curves occur (flexures).

I adopted this method long ago for the œsophagus (as did Ach*), in connection with the physiological investigations which have been mentioned above. The apparatus consists of an ordinary, non-extensible œsophagoscope, to which may be adapted a small closing cap provided with a sloping pane of looking-glass. The cap is air-tight, and provided with a lateral tube for the attachment of an india-rubber inflator. A manometer, such as I used always to introduce into the tubes, can be dispensed with in practice; for there is not much danger of using excessive pressure, as the air rapidly escapes into the stomach, and the subject complains if the stomach is too full. Besides, pressure cannot be accurately checked on account of the considerable oscillations of respiration, deglutition, and pulsation.

It is clear at the outset that the "pneumatic œsophagoscope" cannot fulfil the object which Strauss aimed at—*i.e.*, easy introduction—as the air is not able to dilate the hypopharynx, and in the lower sections there is usually no obstruction to overcome. Moreover, the advantage of the method for the œsophagus is limited in many cases by the closing cap rendering the employment of any operating instrument, and even the indispensable cleansing of the field of vision, impossible. Nevertheless, it appears to me that there are a few indications for it which I may briefly summarize below. I will add, however, that I have not been able as yet to test the pneumatic method in every case, and consequently I will limit myself for the most part to making suggestions.

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* *Münch. Med. Wochenschr.*, 1908, No. 44.

If air is slowly pumped into the œsophagus when the tube is fairly high up, the lumen is developed in inverse proportion to the varying strength of external resistance. The mouth of the œsophagus does not allow any air to escape past the tube, even when there is a high degree of pressure and expansion of the stomach. In the cervical section an enlargement of the lumen increasing downwards funnel-wise is observed, but this scarcely exceeds the diameter of from 0·5 to 1 centimetre. The lumen, however, increases remarkably in the thoracic section and especially in the pars infrabifurcalis. The increase of diameter is not equal on all sides but is most marked laterally, so that the bifurcation constriction and the aorta constriction become very prominent. They generally stand out in the lumen to such an extent that, in spite of the average width of the passage being 2 to 3 centimetres, it is not possible to see as far as the hiatus œsophageus.

The diaphragmatic constriction also appears during dilatation with great distinctness as a sharp band ; normally it appears as a complete fissure-like occlusion, but masses of mucus are often seen moving up and down in the hiatus with the respiratory movements.

I am hoping for some practical advantage from pneumatic œsophagoscopy, especially in the case of spasms, pareses, and dilatations, which often present great difficulties in diagnosis. Motor disturbances may depart in two directions from the normal physiological behaviour described above. Expansibility may be diminished, or even aboblished, through abnormal reflex contraction, or else expansion may meet with such an abnormally slight resistance that there is then no reflex peristalsis at all. Any existing dilatation, the recognition (in slighter degrees) and estimation of which (at an advanced stage) would otherwise be doubtful, would become very prominent. For the pneumatic method it is indifferent whether the cardia is air-tight or not, as the air finds an adequate resistance at the pylorus for any admissible degree of inflation.

Doubtless the diagnosis of an anatomical or spastic stenosis is aided by the process of inflation, as the form and position of any constriction or increased resistance is shown sharply against the expanded lumen. This method may also serve to locate the cardia, which is often difficult to see, and lies very excentrically, in dilatation of spasmodic origin, and so entrance into the stomach is facilitated.

The procedure in pneumatic œsophagoscopy is exceedingly simple, and requires no further description. There seems to me to be no danger whatever, provided that due attention is paid to the sensations of the patient, such as a feeling of pressure in the stomach.

2. Œsophagoscopic Dilatation.

The temptation to apply this pneumatic procedure to the extrication of foreign bodies induces me to dwell here on the œsophagoscopic treatment of such cases.

In the first place it must be stated that the endoscopic extraction of large and difficult foreign bodies is even now unreliable and dangerous. If the tooth-plate, which is so often swallowed, is taken as an example, it is found from Starck's statistics that only in five instances out of the fifteen similar cases published up to 1905, could the foreign body be extracted through the natural passage. Four times it was pushed intentionally or unintentionally into the stomach, and five times it was removed by external œsophagotomy. I myself experienced the greatest difficulties in extracting a tooth-plate in two out of three cases, and the success of the operation was very dubious, in spite of the fact that I had a perfect set of instruments.

These figures show strongly the necessity for special experience in extracting large and dangerous foreign bodies. Two ways are open: either breaking up the object or dilatation of the œsophagus. As regards the former, Killian succeeded in one instance in getting a galvano-caustic steel-wire snare round the foreign body (vulcanite plate), and, after burning through it, was able to extract the fragments. For a similar object an ingenious galvano-caustic knife-shaped instrument, with permanent air cooling, was constructed by von Miculicz, but its practical utility has not yet been tested. In order not to be limited to objects capable of being burnt, I had a forceps made for breaking up objects, but owing to its undoubted danger I had to refrain from using it, and I find the same objection applies to a breaking forceps sent me by the firm of Eschbaum. It appears that all similar instruments, if they are to be sufficiently strong, are so bulky that their operation in the narrow tube cannot be controlled by the eye. It must also be remembered that the violent breaking or cutting of plate-shaped bodies (which are those generally in question) may be dangerous, because the object is apt to twist or slip away in the process.

I was, therefore, very soon led to try the second way, as I was convinced that by suitable dilatation of the œsophagus it must be possible to bring swallowed objects upwards again in every case. Various experiments had previously been made in this direction also; thus, Heule had invented a distensible rubber ball, Rosenheim an umbrella-like dilator, and so on. The common fault of these instruments seems to me to be that they widen the œsophagus excentrically in all directions, whereas large foreign bodies, which are never globular, always become jammed in one direction—generally the frontal. But if a dilatation is made perpendicularly to this, the tension of the œsophageal tube in the direction of jamming is, of course, only increased. Another fault is that no known dilator permits of the simultaneous use of extracting instruments, and that the degree of expansion can only be regulated and controlled imperfectly.

From these remarks it appears that pneumatic œsophagoscopy is not suitable for the extraction of impacted bodies, because the closing cap renders the use of forceps during inflation impossible, and also because the regio retrolaryngealis is not widened at all in the process. It is not denied, however, that the method is capable of rendering valuable service in diagnosis—such as the recognition of the exact situation, form and size of foreign bodies.

After a consideration of these various points I have evolved a "dilatation œsophagoscope," the practical utility of which has fulfilled expectations. The principles of the instrument are briefly as follows (see Fig. 94):

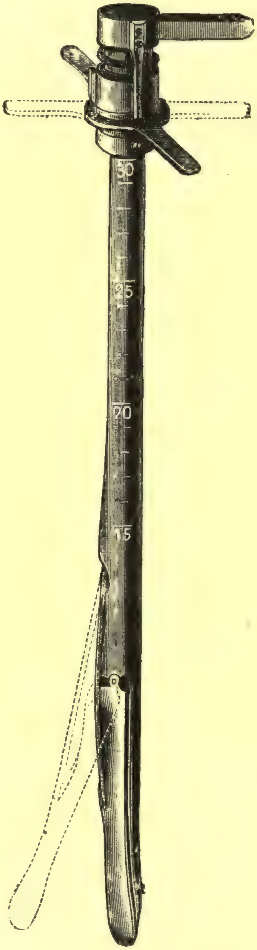

Fig. 94.—Dilatation Œsophagoscope. (After Brünings.)

1. Dilatation is effected unilaterally by one half of an œsophagoscopic tube being able to be spread open in its lower section. The other unmoved half therefore remains within the field of vision, thereby making it possible for the surgeon to keep his eye on the end of the foreign body and to apply the forceps to it.

2. The spreading out is effected by a lever situated outside, and may be read off from a centimetre scale. It extends up to a maximum width of 5·5 centimetres.

3. In order to make its use safe, I have arranged it so that, when the maximum expansion is exceeded, the instrument automatically closes again. It is also arranged so that, in case of too great a resistance, the draw-wire will break at a certain point. The ends are surrounded by an elastic wire spiral and so cannot inflict any injury.

4. The dilatation œsophagoscope may be easily introduced without a mandrin, and leaves the entire field of vision free.

The employment of the instrument, which is at present meant only for use in the pars suprabifurcalis (35 centimetres), as by far the greater number of foreign bodies are situated high up, must be as follows:

The tube is introduced by feel in the closed position. This is quite easy, as the flattened beak-shaped end maintains a frontal position. After the œsophageal orifice has been passed by 3 to 5 centimetres—*i.e.*, at a total depth of introduction of 18 to 20 centimetres, as read on the scale—the instrument is fitted with the electroscope and turned 90°, so that spreading takes place in the frontal plane. A dilatation of about 1·5 centimetres is made, and the forceps passed on to the foreign body under accurate control of the eye. It is advisable to grasp the higher end, corresponding to the immovable half of the tube--never the middle—with the forceps, and, if possible, to fix them firmly on to the foreign body by means of the stopping screw.

The dilatation proper, or attempt at dislodgment, now follows. The tubes gradually spread whilst the direction of impaction is closely observed and the scale constantly checked. At each dilatation an attempt is made to effect a dislodgment or turning with the forceps. With adults the unilateral dilatation may be carried to 5·5 centimetres without danger, but usually a lesser degree will serve for dislodgment. When that is the case, there are two possibilities as regards extraction. Bodies which are dangerously sharp, but not too large, may be drawn a little way into the end of the dilator, so as to be just covered by the distended branches, and so be extracted under their protection. In the case of large objects, however, the surgeon must generally be content with loosening or turning, and then conveying the object to the surface in immediate contact with the dilated end of the tube. The conical form of the extended dilator admits of a very considerable widening taking place in the region of the pars retrolaryngealis.

I have extracted a sharp piece of bone by using the first method. When the instrument reached a spread of some 3 centimetres the body was completely embraced by the branches of the œsophagoscope, and in this position was brought through the œsophageal orifice. The whole process was accomplished quite smoothly in about three minutes' time.

The employment of the dilatation œsophagoscope in the thoracic and lower cervical section presents no difficulties, and it may in some cases even be introduced through an œsophagotomy wound; but the method must often fail in the case of foreign bodies impacted in the immediate proximity of the œsophageal orifice. What renders matters so difficult is the reflex spasm, which generally persists here, and which cannot be much reduced by anæsthesia of the mucous membrane. The stimuli from the stretching exerted by large foreign bodies is certainly not transmitted by nerves in the mucous membrane, and does not seem to act directly on the muscles, and the reflex must be regarded as being produced from the deep nerve plexuses of the œsophageal wall and transmitted thence to the centre. Consequently, as there can be no question of anæsthetizing the œsophageal wall by infiltration, an attempt must be made to interrupt the reflex arc by means of general anæsthesia of a sufficient depth.

In discussing œsophagoscopic dilatation, some mention must be made of the procedure in treating stenoses, the general preliminaries of which I have already mentioned. A strict distinction must be made between the expansile treatment of spastic contractions, such as occur in all parts of the œsophagus but especially at the cardia, and the dilatation of anatomical stenoses. In the former case the object is to overcome an abnormal functional resistance (contraction) by force—whether with or without the tearing of muscular fibres it is not necessary to inquire; in the second case, by means of a steadily repeated slight but persistent overpassing of the limit of elasticity—not the limit of solidity—a non-contractile tissue has to be expanded. Therefore, in the treatment of spastic stenoses, only quickly-operating dilators, which can be exactly regulated and located, are suitable, whereas in scar strictures only the slow continuous action of the bougie is effective.

I have already described suitable "dynamometric dilatators" for the cardia and the œsophageal orifice. A description of the mode of application would go beyond the scope of this book, because œsophagoscopic method only plays a subordinate rôle here. But I will say that the instruments fulfil their purpose excellently, and may be considered as the best method of treating spastic stenoses.

The part played by œsophagoscopy in the dilatation of anatomical stenoses is more important, especially in those caused by corrosive fluids, and it is in many respects an improvement on the imperfect results of using the blind bougie. It is now known that bougie dilatation, guided by the eye, frequently finds the passage, whereas proceeding only by feel fails, especially in cases where an excentric lumen or pouch formation not only renders such a blind method impossible but also very dangerous. According to von Hacker's experience, the majority of patients afflicted with severe excentric stenoses (1 to 3 millimetres) die sooner or later from perforation with the bougie.

In cases where the stenosis feels impermeable by the bougie, the exact location of the stenosis must in the first place be ascertained by œsophagoscopy, as the knowledge of this frequently allows of the introduction of a thin elastic bougie with a wire mandrin into the lumen when it is accurately presented. It is desirable to give the end of the bougie a suitable curve by bending the wire mandrin. The introduction of the tube even at the second or third application may then often be dispensed with, and the passage found with the bougie when once its position and direction are known. When stenoses occur at different points or in different degrees, a progressive dilatation is often all that is possible, and this should, if possible, be carried far enough in each section for the thinnest œsophagoscopic tube to be passed. Here, as a last resort, the method of laminaria treatment, evolved by Ebstein* in Störk's clinic, may be suitable, notwithstanding the objections to a general employment of this method mentioned above. For the introduction of the tent one of the forceps can be used. The varying duration of the time of the introduction renders a kind of graduation possible, though this is rather uncertain, and it would be advisable to test the swelling capacity of the laminaria employed by experiments in water at the temperature of the body.

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* *Wiener Klin. Wochenschr.*, 1898, No. 6.

In advanced cases, von Hacker has prescribed the elegant method of "the endless bougie," after gastrostomy. The use of ivory olives, as hitherto practised, seems to me, however, not very suitable, as they bring about a too sudden expansion with no lasting effect. I have therefore, for this purpose, had a set of short elastic bougies (10 centimetres) prepared, with both ends rounded. The bougies are slightly conical, and join on to each other in such a way as to produce a quite continuous increase of thickness. This, as distinct from the olive, avoids any sudden expansion. The gastrostomy required for the endless bougie renders possible a procedure known as

3. Retrograde Œsophagoscopy,

about which I will, in conclusion, say a few words.

The experience that strictures with complicated conditions of the lumen are only passable for the probe on one side suggested to Ehrlich* the idea of reaching the œsophagus from the stomach, and exploring it by means of a bougie through a gastrostomy wound. After many vain attempts he accidentally succeeded. Later authors (see Starck) have not always succeeded in discovering the gastric entrance of the cardia, the difficulties arising chiefly from the unfavourable situation and direction of the gastrostomy wound and from orientation in the collapsed stomach being rendered difficult by the constant secretion. It is, therefore, advisable to perform gastrostomy as near to the cardia as possible, and to introduce the tube immediately after the operation. I suspect that the procedure of inflating with air would render good service here, because it gets rid of interference by secretion, and secures a free view and easy mobility in the stomach.

Retrograde œsophagoscopy is best carried out with the upper part of the body as low as possible, and after the stomach has been well washed out. As instruments, the open tube spatulæ are the most suitable.

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* *Berliner Klin. Wochenschr.*, 1898, No. 42.

Among the chief indications, I should like to mention cases of severe chronic spasm of the cardia with diffuse widening of the œsophagus, when the oral introduction of the dynamometric dilatator may fail.* If the cardia can be passed from the stomach, no doubt complete success may be attained by dilatation systematically continued, without the patient being exposed to the serious danger of von Miculicz's operation. Further, retrograde œsophagoscopy may be similarly useful for treating scar tissue stenoses with a bougie. Also, in the case of foreign bodies jammed in the œsophagus near the cardia, when oral œsophagoscopy has failed, as these may be extracted through the cardia with the help of the dilatation œsophagoscope.

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* If, owing to the excentric position of the cardia, the passing of the dilators presents difficulties, the surgeon might try to replace the rubber olive, which may be screwed off, by diverticulum end-pieces of varying curvature.

CHAPTER VIII

BRONCHOSCOPIC OPERATIONS AND METHODS OF TREATMENT

AMONG all bronchoscopic operations, the removal of foreign bodies which have been inhaled easily takes the first place, not only on account of the frequency of their occurrence, but also on account of the importance of their removal as a life-saving device. The question of removal must at this point receive detailed attention first of all, but at the same time the diagnosis and pathology of foreign bodies must not be neglected. I should like, in accordance with the object of this book, to simplify the main therapeutic difficulties, in particular the technique of the extraction, although I am quite aware that the description of an operative technique which affords such an unlimited scope to personal skill, ingenuity, and talent for mechanical adaptability, encounters quite special difficulties.

I. DIAGNOSIS AND THERAPEUTICS OF FOREIGN BODIES IN THE BRONCHI.

1. General Purport of the Method.

Thirteen years have passed since Killian first removed a foreign body by means of direct upper bronchoscopy. Accounts of about 600 successful bronchoscopic extractions of foreign bodies have been published during this time, and very many more must remain unpublished. Kahler, to whose report at the Third International Laryngo-Rhinological Congress (Berlin) I frequently refer in the following account, rightly says that the publication of simple uncomplicated cases of foreign bodies has already gradually lost all interest. I myself have only published from my series those cases which for any special reason could be considered instructive. And so it may be supposed, without much likelihood of error, that the true number of successful bronchoscopical extractions can no longer be exactly computed, and in any case reaches far more than 600.

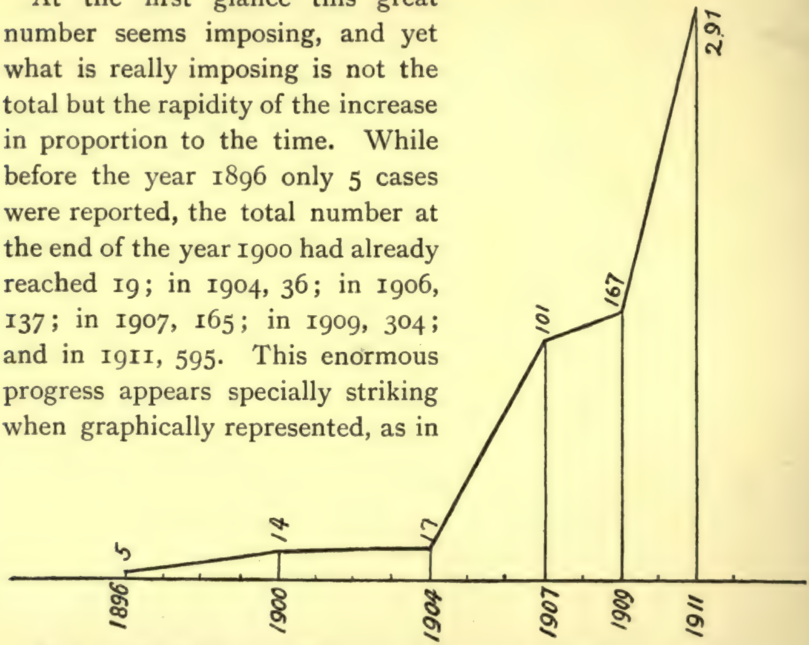

Fig. 95.—Curve showing Progressive Increase in Number of Foreign Bodies extracted from 1896-1911.

At the first glance this great number seems imposing, and yet what is really imposing is not the total but the rapidity of the increase in proportion to the time. While before the year 1896 only 5 cases were reported, the total number at the end of the year 1900 had already reached 19; in 1904, 36; in 1906, 137; in 1907, 165; in 1909, 304; and in 1911, 595. This enormous progress appears specially striking when graphically represented, as in Fig. 95. The reasons for the enormous increase in the number of foreign bodies diagnosed and extracted by bronchoscopy are mainly two. Firstly, each surgeon who practises bronchoscopy propagates the method, and by successful operations attracts attention and gains confidence for it among the medical profession and the public. In this way an increase takes place in personal local statistics, for which I can give as an example the figures of Killian.* Still more striking are the figures from the Breslau surgical clinic, which I have also represented graphically (Fig. 96).

The second and far more practical way is that a number of bronchoscopically efficient practitioners is arising in the country, each of whom in his turn is interested in every possible way in the local introduction of the method. The rate at which this form of progress is taking place has been discussed by Killian in his paper before the Third International Laryngological Congress at Berlin in 1911;† and I myself, at Jena, in the last year and a half, have already (endoscopically) instructed over 100 surgeons in weekly demonstrations. How far these numbers are short of the truth is shown by the fact that my own instrumentarium has been used in over 1,000 cases. It seems to me that statistics on foreign bodies would show quite different numbers if the local propaganda of Killian's method had been carried on everywhere with sufficient vigour. The fact that already in the first year of my practice in the Jena

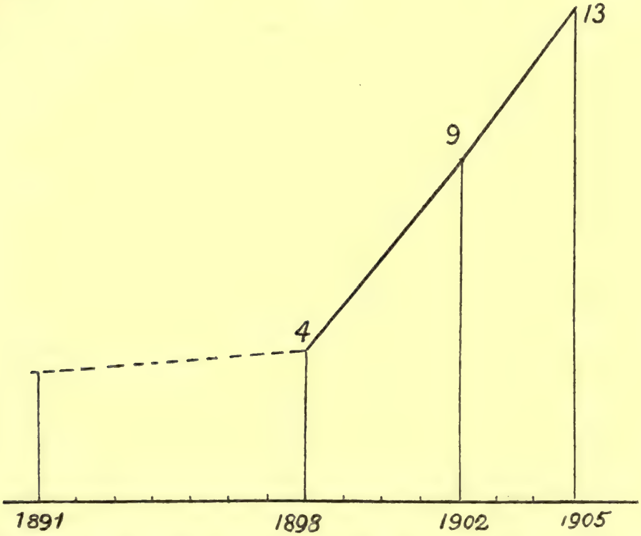

Fig. 96.—Curve of Foreign Bodies from the Breslau Surgical Clinic.

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* *Arch. f. Laryngol.*, 1904, Bd. 15.

† *Cf.* also Killian, "Zur Geschichte der Bronchoskopie und Œsophagoskopie," *Deutsche Med. Woch.*, 1911, No. 35.

clinic nine foreign bodies, five of which were in the windpipe, were removed by endoscopic means, all of which arose in the locality and its surroundings, may illustrate what may be attained by these means. This extraordinarily high number, compared with the former figures, appears likely to be surpassed in this second year. The method has been introduced, and is now recognized, in Jena and its neighbourhood (Thuringia).

These are certainly the first cases of endoscopically extracted foreign bodies which our small University has to show. Most of my colleagues here knew the foreign body in the bronchus from hearsay only, and their surprised inquiries concerning the cause of this sudden increase in foreign bodies may be understood. The answer is simple. Professor Wittmaack and I have propagated and recommended the knowledge in Jena, as well as in other neighbouring towns of Thuringia, by demonstrations and extension lectures for general practitioners; have directed observation to the appearances, the frequency, and the dangers, of foreign bodies which have been inhaled; and have not omitted the consideration of the evidence of successful operations in local medical journals. Without doubt, enough has not yet been done in this direction. How can it, then, be understood that so little is heard of the extraction of foreign bodies in many great cities—above all in Berlin, with its millions of inhabitants? Bronchoscopic literature receives attention almost exclusively in technical journals, whereas it is of extreme importance that the general practitioner should be acquainted with this branch of the study. Bronchial foreign bodies give rise, apart from the rare cases of suffocation, to many symptoms of lung disease. The patient goes to a physician, and, unfortunately, not infrequently has the experience that the affection is misinterpreted, and that, too, after searching inquiries into the history of the case. This latter is not always a matter for reproach, considering how uncertain and complicated the history can be, and, in most cases where children are concerned, often is. Moreover, it must be considered that, in many cases, foreign bodies never give rise to any symptoms, still less to the characteristic ones, and so are not traceable with certainty by any of the usual methods of clinical research. Because, in the most favourable cases, the diagnosis will rest only on the supposition of a foreign body, independent of the greater or lesser probability, the doctors should always justify it by bronchoscopy, even if this only occurs in one case out of ten. If the curve of frequency of foreign bodies is looked at once more, and the extraordinarily great increase considered, the reflection will occur that the previous extractions are associated with a relatively small number of names, which in Germany, for example, are to a certain extent concerned with but a small series of foreign bodies. It also becomes clearly evident that the status of bronchoscopy at the present time gives, as yet, an absolutely incomplete picture of the part which it will play in the hands of the specialist in the future. Surely even Killian never anticipated this development of the subject on the occasion of his first successful extractions thirteen years ago. Requirements often only come to light after the possibility of satisfactory results is established. After these general remarks, it is worth while to look again at the special services of tracheo-bronchoscopy for the recognition and treatment of foreign bodies. The diagnosis of the foreign body has become possible, in almost every instance, only since the employment of the direct method. Only in 7 per cent. of all published cases could the foreign body not be detected by bronchoscopy, and of these the cause of the failure in many cases was due to insufficient practice or unnecessary instruments, seeing that in the statistics of the last two years, of 291 cases, only two—*i.e.*, 0·7 per cent. of the cases of foreign bodies—could not be seen (Kahler).

With reference to the service rendered by tracheo-bronchoscopy as a therapeutic method, I shall now follow the statistics of Kahler, in which he passes in review the persons suffering from foreign bodies in the time before the existence of bronchoscopy. According to Tuffier, up to 1897, out of eleven cases of pneumonia due to foreign bodies, the supposed foreign body was, on ten occasions not discovered; in four cases the operation resulted in death, and Karewsky in 1903, out of fourteen cases of thoracotomy for foreign bodies, could only point to two successes.

It is therefore not to be wondered at that many authors advise, in cases of foreign bodies, the adoption of an expectant line of treatment. Thus Weist, after the study of 1,000 cases, advised that, unless dangerous symptoms supervened, foreign bodies impacted in the trachea or bronchial tubes should not be operated on, and that the surgeon should wait for spontaneous expulsion. No further remarks are needed to show that this aspect of the matter cannot be approved of, in view of the relative rarity of cases of spontaneous healing through coughing up, which amount, according to the statistics of Preobraschenski and Pohl, only to 218 cases out of 1,064—*i.e.*, 20·5 per cent.

The mortality from inhaled foreign bodies was formerly very large. Thus, among untreated cases, more than 770 cases were reported, according to Preobraschenski—*i.e.*, 52 per cent. This number is, however, certainly too small when it is considered how many patients die of lung complications which can be attributed to foreign bodies not diagnosed. The mortality has, at all events, decreased since the discovery of laryngoscopy because the means of healing laryngeal foreign bodies have been improved. Whilst in prelaryngoscopic times the mortality was 41·2 per cent., it has from 1866 to 1891 been reduced to 30 per cent. The results during the next ten years, till 1901, are still better. Pohl, who carried on the statistical work of Preobraschenski and collected 294 cases from the literature, finds a mortality of 15 per cent. If the treated cases (530) only are considered in the series above mentioned, the mortality amounts to 20·8 per cent. from 1890 till 1901.

If these figures are compared with the bronchoscopic period, it must be considered, in estimating the real value of the progress, that the new method has only just in the present time outgrown its infancy. The method has for the most part been handled by beginners, many of whom, besides, have worked with imperfect and unsuitable instruments. In spite of this, the statistics of von Eicken show, in a series of more than 300 cases (to the beginning of 1909), a very important decrease in mortality as compared with former times—viz., 13·1 per cent. against 52 per cent.

(exclusive of foreign bodies in the larynx). In the statistics of the last two years collected by Kahler, the proportion has become substantially better; out of 291 cases, only 27—*i.e.*, 9·6 per cent. —resulted in death. A considerable number of these fatalities arose from accidental circumstances, and not a single one can be laid to the charge of the method as such. Its essential function—*i.e.*, the extraction of the foreign body—in the statistics of von Eicken was attained in all but 11 per cent. of the cases. Kahler finds among 291 patients during the last two years only 4·5 per cent. cases of failure—" clear evidence indeed of improvement in the technique and in the instruments." If in spite of this a mortality of 9·6 per cent. still remains, it must be sought in the numerous cases of lung complications engendered by the effects of the long duration of the foreign body, which remain even after successful extraction. In the future, treatment of the patient in the early stages should only be taken into consideration, as the prognosis of the acute foreign body is the only one that can be considered as thoroughly favourable.

I am, however, of the opinion that these numbers, encouraging as they are in themselves, are far from presenting a sufficient testimony to the value of bronchoscopy for foreign bodies. What formerly happened to patients like those mentioned above, coming to the clinic with suspected or obvious foreign bodies, who could not be cured without exception? Half of them died from the lingering consequences of the foreign bodies, undiagnosed.

One real value of Killian's method lies in the fact that it teaches the general practitioner the importance of no longer being content to diagnose a circumscript bronchitis, bronchiectasis, chronic pneumonia or abscess of the lungs, and of seeking the aid of a skilled bronchoscopic specialist.

2. The Mechanism of Aspiration and Retention.

In order that foreign bodies may enter the bronchial tree and be impacted in it, a series of mechanisms for protecting the organism must be overcome. The first of these is the extreme degree of sensitiveness of the larynx and the epiglottis against contact, and the rapidity of the reflex closing of the glottis when this occurs. In spite of this, light foreign bodies, swept along by the velocity of the inspiratory current of air, will more often pass the open glottis if the air current is not interrupted by the epiglottis. I consider that the chief function of this structure is a protective one against the entrance of foreign bodies carried in the air; in any case, the function formerly ascribed to it—namely, that of closing the entrance to the larynx during the act of swallowing—is absolutely without foundation.

Foreign bodies will thus be drawn into the air-passages if the mechanism just referred to fails, or when the sensibility is disturbed, as on taking an inspiration with the mouth full, or if the epiglottis is absent or is abnormally constituted, or when a number of these conditions go together. As a matter of fact, in most of the cases of foreign bodies where the history has been elucidated, the story is that when the mouth was full a violent and unexpected inspiration (sneezing, laughing, etc.) was taken, or, when eating with a spoon, its contents were "gulped" down with a sudden inspiration, or, finally, that the inspiration took place unconsciously during sleep.

For the same reason it may be understood that foreign bodies are generally inspired during childhood. According to the statistics prepared by Gottstein, 63 per cent. of the cases were in children; in his private practice, as well as in mine, the percentage was even considerably higher. These facts must not only be ascribed to the inexperience of children, and to the imperfectly-adjusted mechanism for protecting the air-passages, but also to the bad habit which children have of putting all kinds of things into their mouths. Many cases give a history that the foreign body was swallowed at the moment a mother punished her child by a blow. Similarly, it may happen through an accident, such as a fall, a fright, or any accident which causes a sudden inspiration. It has often seemed surprising that the protective mechanism at the junction of the air and food passages does not more often fail, even in the case of adults, during the process of eating and drinking. Certainly adults also "gulp" pretty often, but the consequences are not dangerous, because fluids and soft articles of food are generally promptly coughed or spat out; even soft pieces of meat do not apparently stick, as they are never seen in any collection of foreign bodies from the bronchi that I have come across. When they are abnormally large, so that they stick fast in the larynx or upper air-passages, they cause death through suffocation. If, on the other hand, they get down straight away into the smaller divisions of the bronchial system, and remain impacted there, spontaneous recovery may still take place owing to the rapid disintegration which ensues. Substances, however, like fresh fruit, especially when unripe, dried shell fruits, and the pips of fruits with peel, often remain in the moist and warm recesses of the bronchial tree, and resist decomposition so long that a serious affection of the lungs may occur.

Particularly favourable conditions for spontaneous cure occur in the case of readily soluble substances—sweets, chocolate, etc., and so cases of this kind, in children, hardly ever come up for treatment. On a ski-ing tour I once inhaled with a sudden deep inspiration a lump of frozen snow, which I was allowing to dissolve in my mouth. The momentary feeling of suffocation was rather strong, but disappeared in the course of a minute or two.

What is the situation with regard to hard, non-friable, and insoluble foreign bodies? If they are very small, so that they enter the lungs suspended in the form of dust, spontaneous ejection occurs by means of mucous secretion, ciliary action, and coughing. It is only when large quantities of dust are inhaled that definite lung affections, such as stonemason's phthisis, occur. Larger particles, up to 2 or 3 millimetres in diameter, often have a good chance, because their surface area is relatively great compared with their weight, and therefore presents a relatively large surface to the action of the ciliated epithelium. The specific weight of the inhaled matter here plays an important part; thus, small fruit pips and the like are scarcely ever retained, whilst, for instance, a piece of tooth-filling is only got rid of spontaneously with the greatest difficulty.

The typical bronchial foreign body, as observed in more than

90 per cent. of cases, is after all of a firm, relatively heavy type, of a size which enables it to stick in the main bronchus or its larger subdivisions.*

It is in the majority of cases localized in the right main bronchus, according to Gottstein's statistics, in men in four cases out of five, in women in two cases out of three.

It is not possible here to enumerate in detail the various kinds of foreign bodies and the frequency of their occurrence.

Pieces of bone are the most frequent, after that beans and similar vegetable matter with the same tendency to swell, then sharp foreign bodies such as nails and needles. Further may be mentioned teeth, false teeth, hollow bodies (fragments of canulas, pencil-covers, penholders, and the like), pips and stones of different kinds of fruits, ears of corn, small metal objects, shirt buttons, collar studs, cherry stones, prune stones, nutshells, coins, steel pens, glass beads, pebble stones, fish-bones.

How is it that these articles are retained in the lower air-passages? In what does the mechanism of retention really consist? Before pursuing the question further, I should like to show here an interesting table of Gottstein's, of foreign bodies which have been coughed up spontaneously. The table is arranged in typical groups, and dates from the prebronchoscopic period.†

Type of Foreign Body.	Total Number.	Expectorated without Tracheotomy.	Expectorated through Tracheotomy Wound.
		Per Cent.	Per Cent.
Rough, sharp-edged ...	183	39	6·5
Smooth, round	103	32	32
Bodies liable to swell ...	101	11	20
Pointed	45	29	11
Smooth, flat	32	37	19
Hollow bodies	25	12	8

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* Killian, "Zur Behandlung der Fremdkörper in den tieferen Luftwegen," usw., *Zeitschrift für Ohrenheilk.*, usw., Bd. 55, No. 1.

† "Ueber die Diagnose und Therapie der Fremdkörper," usw., *Mitteilungen a. d. Grenzgebieten d. Medizin u. Chirurgie,* supplementary vol. iii., 1907.

Before coming to details, it may be asked why foreign bodies are retained at all, why the natural protective mechanisms of the organism—coughing, ciliary action, and secretion—do not suffice in every case to expel the object. The physiology of respiration certainly teaches that expiratory pressure is far greater than inspiratory pressure. In the case of a forced expiration it amounts to 85 to 100 millimetres mercury; in the case of reflex expirations, such as coughing and sneezing, it is distinctly higher. A forced inspiration, on the other hand, registers a pressure of about 50 millimetres mercury.

It would naturally be expected that every foreign body would be expelled by the cough which it naturally provokes. How often this really happens is not known ; in any case, on closer observation, a succession of mechanical forces may be observed which afford some explanation of the retention which so often occurs.

In the first place it must be mentioned that the inspiratory force with which a foreign body is drawn into the bronchial tree is aided by two very material factors. The one is that the direction coincides with that of gravity, and the other the suction-tube action. If a projectile is drawn into the wider end of a conical tube with a diminishing lumen and cannot pass through the narrow end, then it must wedge itself in with the whole energy that it has acquired on the distance travelled, and it is out of the question to displace the projectile with an equal air-pressure acting from the narrow end.

The less energy that is expended by the foreign body in overcoming angular turnings in the bronchial tree, the more powerful will this suction action become. In every case the foreign body must come to a place in the main path where it becomes more or less firmly impacted, unless it happens to be of such a shape or size that it cannot penetrate at a point of division into the smaller bronchi, and yet, above the point of division, the bronchus is large enough to give it free room for play. In this case it is not retained in the main path, but is arrested at the point of bifurcation without losing its capability of movement. The next cough forces it upwards again, and the process is repeated until it becomes impacted in another place or position. In this eventuality the likelihood of its again being dislodged by coughing is extremely remote.

This process chiefly comes into operation in the case of large rounded objects, which offer a large surface area to the air current; pointed and thin objects come less under the suction action and also offer a proportionately smaller surface to the current of air which is trying to expel them.

The fact that many inhaled bodies "float" must not pass unrecognized, and this is often borne out by the history. The patients state that immediately after "gulping" they experience a choking sensation, which is followed by a period of relief of varying duration. Only occasionally does the "dancing" up and down of the foreign body last for any length of time, which is explained by what has already been stated. It usually only happens when the object is conical and of such a size that it is arrested at the tracheal bifurcation or some lower point of division, and yet has fairly free play in the segment above this. Vegetable matter which swells up may become loose from one position, and "float" for some time before settling down again. The question may be asked, why a foreign body which begins or continues to float does not always find its way back through the glottis. This seems to depend on the fact that the glottic aperture, controlled by the vocal cords, operates rather like a money-box: on inspiration the glottis is widened to its utmost, on expiration it is more or less narrowed. This unfavourable condition is considerably aggravated by the foreign body itself, as the bronchial irritation to which it gives rise provokes a reflex contraction of the aperture of the glottis, which may amount to a definite glottic spasm. Cases have been recorded where an impacted bronchial foreign body gave rise to attacks of laryngeal dyspnœa which lasted for hours at a time. The chief cause of the retention of foreign bodies may then be considered to be dependent on the suction action, on the momentum of the foreign body, and on the money-box-like action of the glottis. It remains to consider what natural means the organism possesses to bring about their expulsion. The first inclination would be to mention reflex cough as the most important, but closer consideration will show that in man this is of very doubtful value. It has been pointed out above that at every forced expiration, and particularly at every cough, the lumen of the trachea and of the larger bronchi diminishes; often in young people, and practically always in the case of children, this amounts to a total collapse. I have observed this latter phenomenon in a very large number of impacted foreign bodies ; in cases where the end of the tube is not directly on top of the foreign body, this disappears at every cough, and only appears again with the next inspiration.

It is easy to see even from models that when a foreign body fills the tube the success of the *vis a tergo* of the expiratory efforts is largely negatived by this diminution in the lumen, and this is even more the case when the respiratory capabilities of the peripheral section of the lungs has been damaged. Coughing has, however, another injurious effect—it is always followed by a forced inspiration, which dilates to its maximum the lumen of the air-passage; and this dilatation, in conjunction with the pressure of the inspiratory blast and with the force of gravity, provides an excellent opportunity for the farther descent of the foreign body.

In practice this gradual downward progress, owing to the valve-like action of the respiratory mechanism, must always be reckoned with. Measures such as lowering the head or inverting the body are usually applied too late to overcome this fatal tendency.

An interesting point brought out in Gottstein's statistics quoted above is that foreign bodies which swell up readily have a greatly increased chance of being expelled spontaneously after tracheotomy has been performed. I cannot bring forward any direct evidence in explanation of this remarkable fact, but I think that the explanation is to be sought in the fact that foreign bodies of this kind find their way back through the larynx with very great difficulty owing to their size. Beans, which are inspired almost without exception by children, are in themselves relatively very large foreign bodies, and become quite remarkably so on account of the swelling which takes place in them. Add to this the relative smallness of the larynx in the child, and the tendency that the subglottic space shows to inflammatory swelling, and it can readily be understood that a wide opening in the trachea forms an excellent point of exit for the foreign body if it becomes disimpacted.

To show that such a release is directly promoted by tracheotomy, the alteration in the expectoration mechanism produced by it must be considered. It has already been shown that the cough loses its characteristic nature of an explosion when the glottis fails to close properly, and therefore the dangerous expiratory collapse of the walls of the bronchi is diminished, although the real expiratory pressure is unaltered. The knowledge of these facts is of the greatest therapeutical importance.

Another point that is noteworthy in the above statistics is the rarity with which pointed or hollow bodies are spontaneously coughed up, compared with smooth and round bodies (11 to 12 per cent. against about 33 per cent.). The explanation lies partly in the small surface area they present to the expiratory blast, and partly in their long shape. Needles, nails, steel pens, and the like, almost always fall with their heavy—*i.e.*, their blunt—end foremost, until this is arrested at some point lower down. The position eventually taken up depends on the width of the bronchial lumen, and is a more oblique one, with the point of the object resting against the wall. Thus the position is a most unfavourable one for an upward movement; and even if this does happily occur, there is always a probability of a repeated arrest at the various angles in the air-passages.

A large number of general and special causes for the retention of "acute" foreign bodies is therefore seen to exist, and in the next section it will be further seen that the organism possesses very insufficient means for expelling "chronic" foreign bodies, or for rendering them harmless. The prognosis of the foreign body *quoad expulsionem* generally becomes worse from day to day. In the case of foreign bodies which are firmly impacted and obstruct the lumen, a noticeable swelling of the bronchial mucosa above the point of retention may be observed after a few hours, and this markedly increases the difficulties of artificial extraction. If the foreign body has sharp corners, so that the mucosa is torn by it at every respiratory movement, granulations appear in a few days or, more rarely, after a week or two. These increase the degree of impaction, and also render bronchoscopic extraction more difficult, owing to their great tendency to bleed. As a further result of the inflammatory reaction, the bronchial wall may be considerably altered, and a scar tissue stenosis may form above the foreign body, and the lumen of the bronchus become almost unrecognizable.

If matters progress as far as this, the organism is deprived of its last mode of action—*i.e.*, expulsion—owing to the increasing pressure of secretion behind the foreign body. The pent-up secretion is pathologically increased, becomes purulent, and soon leads to bronchiectatic dilatation, which however does not usually extend above the point of retention. A local destructive process by which the foreign body might free itself is so rare that the possibility of it practically plays no part. It will be considered in the next section.

3. Symptomatology and Diagnosis.

The diagnosis of a foreign body should begin with an attempt to obtain the history of the case from the patient; but this is not always easy, as the extraordinary explanations often given to account for a supposed foreign body are almost inconceivable. Even educated people have often a very hazy notion of the trachea and bronchi, and their relation to the œsophagus. Uneducated people only know that they swallowed, and something " stuck in their throat " or went down the wrong way. Practically none of them seem to realize that the majority of foreign bodies do not cause suffocation, but usually give rise to a more or less chronic affection of the lungs.

I have come across cases where a doctor, obsessed with the idea that a foreign body in the lower air-passages must cause acute suffocation, had entirely misinterpreted a history which clearly pointed to the presence of a chronic foreign body. The pathology of bronchial foreign bodies, or rather the realization of its importance, is comparatively recent. I cannot remember to have heard anything of it in my student days.

It is important to ascertain clearly at the outset whether a body which disappeared into the mouth reached the œsophagus or the air-passages. In ordinary cases this is not difficult, as foreign bodies which stick in the œsophagus give rise to a localized painful feeling of pressure, and this pain is increased at every swallowing movement, even when saliva only is concerned; unless the foreign body is very small, the swallowing of solids, or even fluids, is impossible.

It should also be remembered that a foreign body in the œsophagus can give rise to spasmodic cough and suffocative attacks. This is especially the case in children, as in their case, not only the pars membranacea but the whole trachea is easily compressed by the foreign body.

The symptoms of a foreign body in the air-passages are quite different. Pain is usually only experienced in the case of foreign bodies in the larynx which may injure the laryngeal mucosa and cause spasm of the glottis. Hoarseness, amounting to complete aphonia, may occur, and this comes on suddenly, immediately after the accident.

Laryngeal dyspnœa usually only occurs with large foreign bodies, but it may occur after an interval owing to reactive swelling of the tissues. With small foreign bodies, however, the feeling of suffocation is only momentary, and is due to the convulsive reflex cough. In adults this cough lacks the characteristic explosive sound, owing to imperfect closure of the glottis, whereas in children, as a result of the expiratory collapse of the bronchial wall lower down, it closely resembles the peculiar ring of the cough in "croup."

It will be seen, therefore, that the history and the present condition are valuable aids to diagnosis in the case of foreign bodies in the larynx, but the surgeon may find them of little value if the foreign body has reached the bronchial tree.

The history generally obtained, most often in the case of children, is that in the middle of a game they were suddenly seized with a convulsive cough and with an intense feeling of suffocation. The mention of this initial attack of coughing is often the only history obtained, and so the matter ends as far as the foreign body is concerned. After this attack an interval of comparative well-being supervenes, and this may last an hour or two or four days, according to the nature of the foreign body, provided that the child keeps quiet. It is usually not necessary to force a patient to keep quiet, as every violent bodily movement is apt to give rise to a feeling of shortness of breath and to a tendency to cough.

Occasionally this reflex cough may lead to another suffocative attack, if the foreign body has become disimpacted and is "dancing" up and down in the trachea, or has been sucked into the bronchus on the sound side. In bad cases these violent attacks may occur at increasingly shorter intervals, and the child may at any moment succumb from exhaustion.

Fortunately, this alarming course of events is not the usual one. Most often the feeling of comparative well-being persists for days or weeks, and only gradually passes over into an indefinite kind of illness, the most prominent symptoms of which are a one-sided bronchial catarrh, with slight rises of temperature. It can readily be understood that, if a doctor is consulted when such symptoms as these occur, the chances of his recognizing their ætiology is often remote, and the child gradually goes downhill. There must be many children who have died from the effects of a chronic foreign body which has not been recognized.

Fortunately, the history, at any rate in those cases that are brought up for an opinion, is often more definite. Mothers have noticed that the child was playing with beans, buttons, nails, or coins, had put one in its mouth, and then suddenly went black in the face with coughing. Adults relate how they swallowed a denture during sleep, or whilst dressing were holding a pin or collar-stud between their teeth, and it slipped down. Or it may be that, whilst drinking soup, they suddenly laughed or spoke and swallowed a piece of bone.

In these cases, not only is the history of swallowing and of the coughing fit quite definite, but the kind of foreign body is also defined: this is a great help. It is possible to note accurately any peculiar features about the foreign body, or perhaps to obtain a similar object and compare its properties with the symptoms that it has occasioned, before deciding on a plan of campaign.

The objective examination of a patient suspected to be suffering from the presence of a bronchial foreign body must be carried out with every means that is at hand, and in the most scientific manner. I must just mention the possibility of the surgeon being misled by a patient who is neurasthenic about foreign bodies, and goes about from surgeon to surgeon with his thousand complaints of superficiality.

The diagnosis is always difficult, in many cases impossible, without bronchoscopy, and in this connection I would urge the use of bronchoscopy ten times too much than once too little.

It is obvious that for the purpose of diagnosis recourse should only be had to the tube when all other methods of investigation have failed, or left the issue in doubt. These methods are: indirect laryngo-tracheoscopy, examination for physical signs in the lungs, radioscopy and radiography, and general clinical observation; on no account should examination with the laryngeal mirror be omitted. I can well remember a case of a patient who was treated for years at the medical clinic for an affection of the lungs which quite incapacitated him from work. At last the possibility of a foreign body was thought of, and, although the radiogram was negative, Killian easily saw, at the first glance in the laryngeal mirror, a white foreign body (collar-stud) impacted in the right main bronchus. It would lead too far to discuss the technique of indirect tracheoscopy, and the means by which it is possible, in favourable cases, to locate a foreign body in the main bronchus; but an excellent description of the procedure obtaining in Killian's clinic is given by Wild.*

The main essentials are a moderately dark room and a well-centred parallel-rayed source of light, such as is afforded by

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* *Beiträge z. Klin. Chirurgie,* Bd. 45.

Kirstein's head-lamp. The wide converging rays which form an ordinary head-mirror illuminate the larynx admirably, but very few light rays can pass farther down. Whenever possible, the use of sunlight and a plain reflector enables tracheoscopy to be carried out quite easily, and the bifurcation of the trachea to be brilliantly illuminated. Unfortunately, examination with the mirror is not usually applicable to children.

With impacted foreign bodies in the bronchi, the vocal cords may often be seen to be more or less adducted. In children a considerable degree of subglottic swelling may be observed, and very often local lesions caused by the foreign body itself or by manipulations carried out by unskilled people can be noticed. In estimating the value of the physical signs in the lungs, a distinction must be made between the "acute" and the "chronic" foreign body. These rather incorrect but well-understood expressions may be allowed for the sake of brevity. The physical signs of "acute" foreign bodies vary in so far as they are impacted or floating, and in so far as they obstruct the bronchus or allow the air to pass. In the trachea floating bodies may, if large enough, give rise to a suction action, the characteristic sound of which can be heard at the other end of the room. At every expiration, and particularly at every cough, they strike against the subglottic space with a loud "flop," and fall back with the succeeding inspiration to a lower position in the trachea. The phenomenon is so characteristic that it cannot possibly be mistaken; it usually only occurs periodically. Thus, a foreign body in the main bronchus may remain there during quiet respiration, but it may be dislodged and forced upwards by a cough. Its contact with the under-surface of the highly irritable vocal cords sets up a whole series of convulsive respiratory efforts which start the occurrence again, and so it goes on until the reflexes of the exhausted and half-asphyxiated patient begin to fail, and he obtains some relief in a period of superficial respiration. I have seen patients brought into the clinic in such a state of collapse that no further anæsthetic was necessary before performing tracheotomy. If the foreign body is impacted—and this, fortunately, is usually the case—the physical signs depend entirely on its size and situation. In this connection it will be well to emphasize a point which appears to be not generally known—namely, that the sudden closure of a main bronchus need not give rise to any subjective or objective symptom of dyspnœa if the other lung is healthy and the patient quiet. This can readily be understood if it is remembered that the gaseous exchange between quiet respiration and that during great activity varies fivefold. One lung is quite capable of taking over the work of the other if the body is at rest. It is not, therefore, necessary to expect suffocative symptoms in every case of a foreign body blocking a main bronchus. I remember a peasant who walked up to the clinic, from whose right bronchus I extracted a piece of a meat bone which was completely blocking it.

It has been mentioned above that smooth foreign bodies which block the bronchus may not even give rise to a coughing attack. The signs of diminished air entry and diminished bronchophony vary in extent with the situation of the foreign body. If the main bronchus is obstructed, retraction of the affected side of the chest, with diminished breath sounds and vocal fremitus over the whole lung, is observed; and as the atelectasis increases, propensive dulling of the percussion note may be observed over the affected area.

The differences on the two sides are very well marked in children, and can often be recognized at a glance. In adults, differences on the two sides are best appreciated by accurate observation in profile, and by palpation of corresponding places. In difficult cases I have found the following device useful. The patient is asked to lie down on a table, and a walking-stick is laid horizontally across his chest; if the movements on both sides are equal, the walking-stick rises and falls parallel with the table. Asymmetrical movements of the stick point to a deficiency in the expansion of one side.

I think that the equality or otherwise of the vocal fremitus is of value, but it seems advisable to use as test words only those which contain deep vowel sounds (*e.g.*, hurrah, cocoa, etc.). In children advantage must be taken of the ordinary noise of crying. Auscultation reveals a closure of the main bronchus by a marked weakening of the vesicular breath sounds over the whole lung. There is, however, never a complete absence of breath sounds, as some are conducted from the other side of the chest, and alterations of pressure in the air contents of the occluded lung may also give rise to feeble vesicular sounds.

These positive signs are extremely valuable; but it is important to remember that relatively large foreign bodies which obstruct a bronchus almost completely may give rise to no alteration in the physical signs in the lungs, so that in the majority of cases this method of observation is apt to be of little value.

In contradistinction to this, however, is the undoubted fact that quite small foreign bodies (such as needles), which irritate the bronchial mucosa, may act on the lung in such a way that diminished respiratory movement results on that side.

Attention must now be turned to a consideration of the symptoms of a more or less chronic foreign body, and it will be seen that they manifest themselves, not as direct foreign body symptoms but as signs of a consecutive bronchial catarrh or other lung disease. I must, however, anticipate these by mentioning the fact that some cases have been recorded where a foreign body has been retained in the bronchus for many years without occasioning any symptoms whatever, and eventually a kind of spontaneous cure has resulted owing to the foreign body becoming encapsulated in connective tissue. This is, however, of so rare an occurrence that practically it may be neglected.

In considering the pathology of bronchial foreign bodies, it is advisable to differentiate the direct local bronchial and peribronchial lesions from the consecutive manifestations which appear in the peripheral portions of the lung affected as a result of infection and pent-up secretion.

The local manifestations often depend on the kind of foreign body that has been inhaled. It has already been remarked that the local lesion produced by a smooth object which obstructs the airway is frequently an acute inflammatory swelling of the mucosa above the point of impaction, and that after extraction this rapidly subsides, and does not result in any destruction of tissue. Pointed objects, on the other hand, often tear the mucous membrane, and after a few days granulations may appear at the edges of the wound.

The most common type of foreign body, however, is one that cannot be described as either quite smooth or yet as definitely pointed. After a few weeks or months a pressure ulcer is produced; this is at first limited to the mucous membrane, whilst some degree of narrowing is produced by the inflammatory swelling in the neighbourhood of the bronchus. After extraction these ulcers heal and leave a scarcely perceptible scar on the mucous membrane, and do not usually result in any alteration of the bronchial lumen. The local lesion is usually accompanied by an irritable bronchial catarrh, with intense injection of the mucosa and increased mucous or muco-purulent secretion.

If the object is not extracted, the ulceration due to the pressure may progress until a local perforation of the bronchial wall, with erosion of the cartilaginous rings or plates, may occur. In the course of years the bronchial wall becomes altered considerably owing to proliferated connective tissue formed from the granulations, and a circular stenosis of scar tissue may result. This stenosis usually forms above the foreign body, which may itself lie in a bronchial lumen of the normal diameter or in a bronchiectatic abscess cavity. As the stenosis has taken some years to form, it is not to be expected that the extraction of the foreign body will have any immediate beneficial influence on it. It is, moreover, due not only to a concentric formation of new connective tissue, but is also due to a scarred crumpling up of the bronchial wall where this has lost its cartilaginous support, and so is not likely to be improved by removal of scar tissue or by cauterization or electrolysis. It should also be borne in mind that it is not merely a membranous diaphragm, but is usually from 1 to 2 centimetres in longitudinal diameter. Peribronchial abscess or gangrene in the neighbourhood of the foreign body only occurs when there has been a perforating wound of the bronchial wall, and this practically never arises spontaneously.

The lung affections which follow the aspiration of a foreign body are seldom of an acute inflammatory type. They are usually due to a downward progression of a bronchitis, which is at first purely local, as the infectious secretion cannot escape very readily, and so the inflammation progresses farther and farther into the periphery of the lobule. So long as the ciliated epithelium is unimpaired, and is able to provide adequate drainage for the finer bronchioles, acute inflammations are improbable.

Acute croupous pneumonia, as a result of an aspirated foreign body, is therefore a rare occurrence. In children, however, a widespread broncho-pneumonia may supervene after twenty-four to forty-eight hours, and may cause a fatal result, although the foreign body has been safely extracted. As a general rule, the severe, acute inflammations are lung abscess and gangrene. The general history is that for days or weeks there were only the manifestations of a slight bronchial catarrh. This is usually unilateral, and confined to the middle or lower lobe. An impacted foreign body may give rise to manifestations on both sides, the reasons for which are not easy to explain.

Catarrh which is confined to the upper lobe is not usually a sign of the presence of a foreign body. At first the bronchitis, especially in adults, is not connected with any rise of temperature; but later there may be small rises, as a stenosis begins to be formed at the site of impaction. After this the course of the illness is rather variable. The bronchitis usually takes on a more marked character, with increased cough and expectoration of purulent or putrid matter. The secretion may be pent up, or bronchiectasis of the whole lobule may take place. A chronic pneumonia may occur over a whole lobe, and convert the peripheral part of the lung into dense connective tissue. The result of this may be that after many years the chronic induration and destructive process has advanced so far that there is produced a veritable honeycomb of connective tissue filled with pus, in which no trace of alveolar epithelium is left.

The patient's general health suffers markedly; he loses weight owing to nights disturbed by uncontrollable fits of coughing and the necessity for getting rid of large quantities of stinking pus. The heart and extremities (clubbing of fingers) show signs of the chronic congestion, and the patient becomes marasmic, or is afflicted with amyloid disease, if he has not previously been carried off by lung abscess, purulent pleurisy, or pulmonary tuberculosis.

It appears superfluous to lay stress on any one point in the general picture due to a chronic foreign body, but it will be well to insist that a bronchial foreign body should always be thought of in all cases of unilateral bronchitis of an obscure type, and in all cases of bronchiectasis or lung abscess, especially when the history affords no guidance.

Gottstein narrates two cases which gradually went from bad to worse as a result of a bronchial foreign body (piece of bone, and collar-stud), without the doctor ever suspecting that anything had been aspirated. In one case post-mortem examination, in the other spontaneous expulsion some years after, cleared up the diagnosis.

The momentarily alarming occurrence of choking is soon forgotten, especially when it is succeeded by the deceptive period of normal well-being, and later on no one thinks of connecting the indefinite lung symptoms with the original accident. The diagnosis is thus often completely obscured, and it has not infrequently happened that an X-ray examination, undertaken for some reason or another, has provided the clue to the difficulty.

It will now be advisable to consider more closely accessory methods of examination.

4. The Diagnostic Value of Röntgen Rays.

Both radioscopy and radiography are useful in the diagnosis of foreign bodies, and each has its own specific value.

Observation with the fluorescent screen is not only quicker and simpler, but is particularly useful in the case of moving objects. The procedure does not necessitate complete immobility on the part of the patient, and thus it is of great value in the examination of dyspnœic persons and restless children. It has the further

PLATE XXIV.

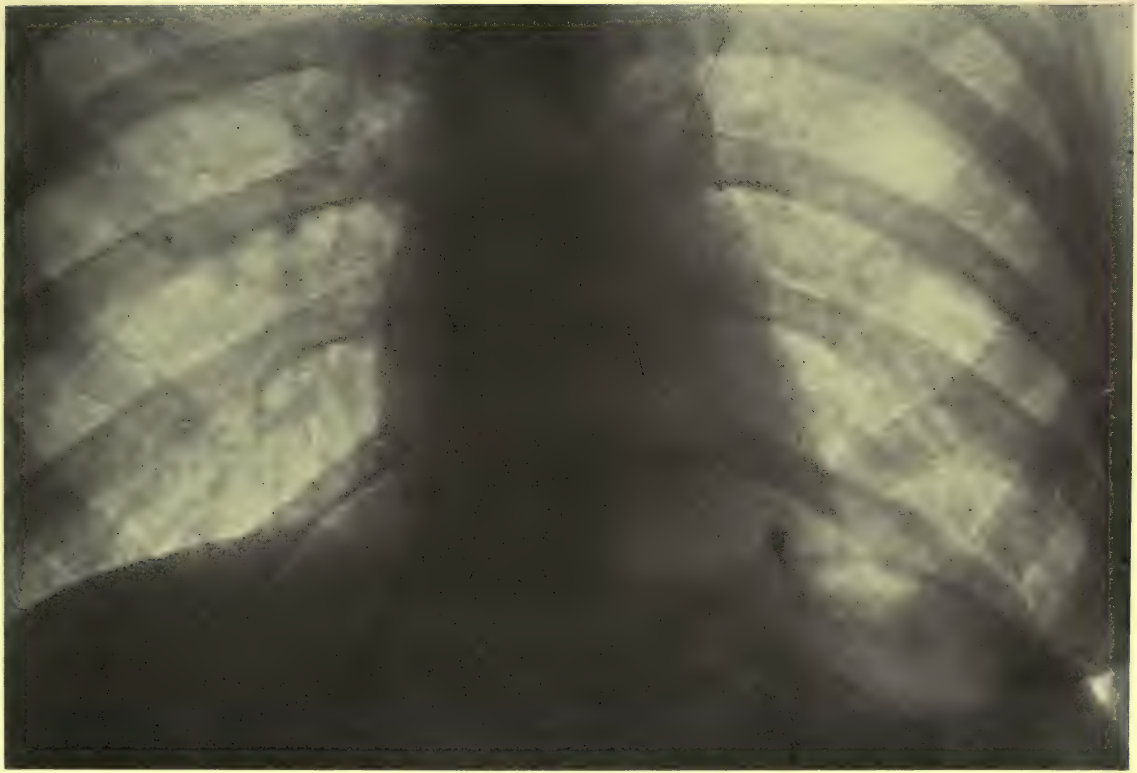

FIG. 97.—SKIAGRAM OF A FOREIGN BODY IN A BRONCHUS OF THE THIRD DEGREE IN THE LEFT LOWER LOBE.

To face page 324.

PLATE XXV.

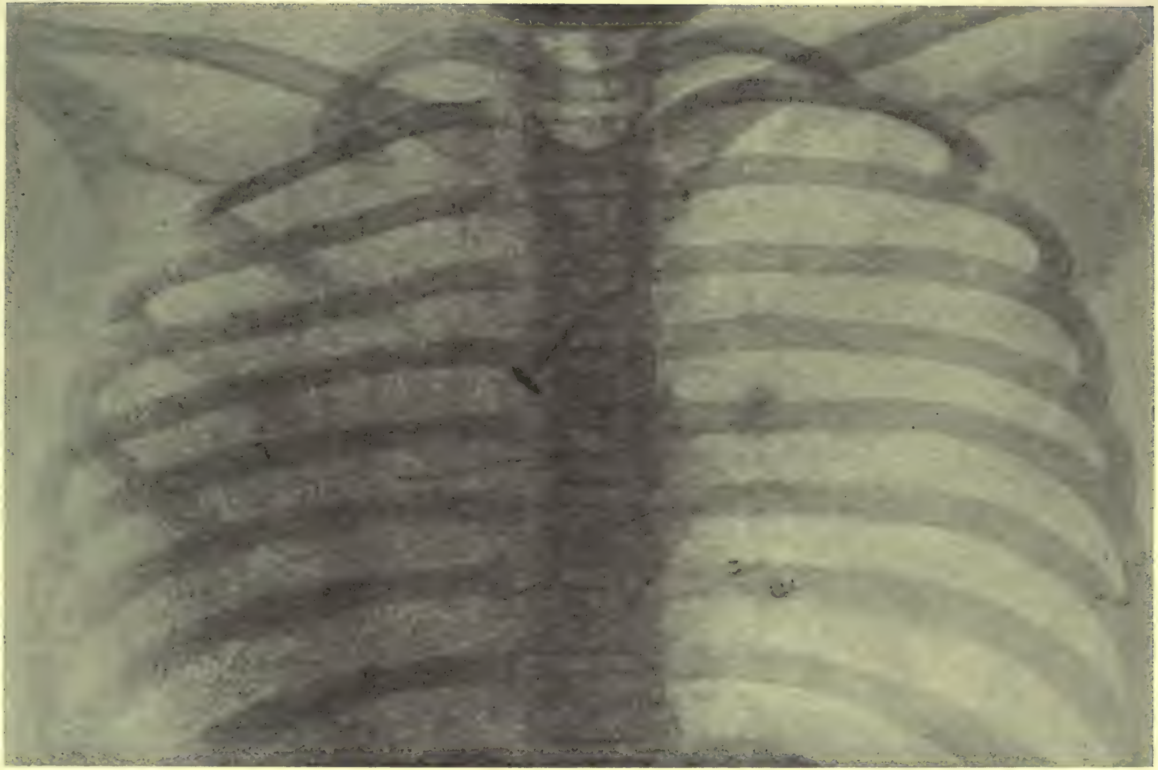

FIG. 98.—FOREIGN BODY (NAIL) IN RIGHT MAIN BRONCHUS. CHRONIC PNEUMONIC THICKENING OF THE WHOLE OF THE RIGHT LUNG. ASYMMETRY OF THE THORAX.

To face page 324.

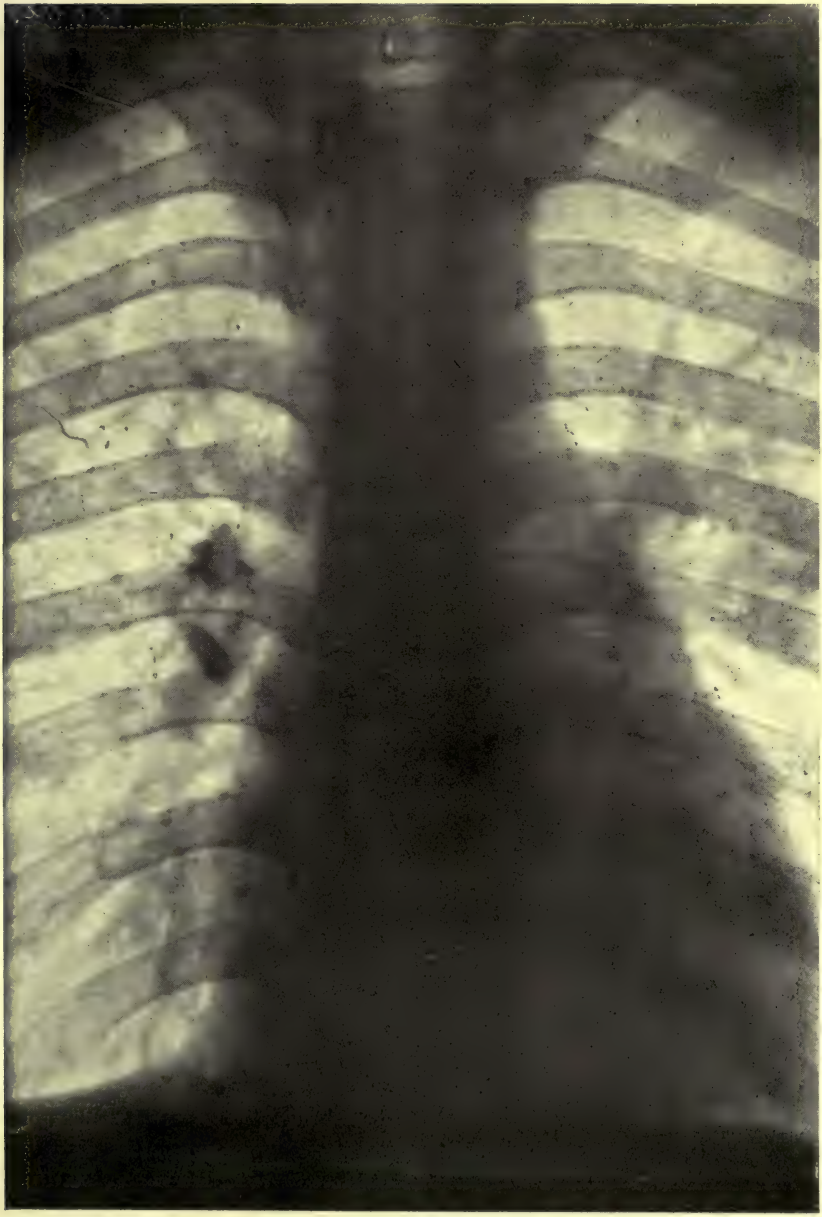

FIG. 99.—SKIAGRAM SHOWING CALCIFIED BRONCHIAL GLANDS IN TYPICAL POSITION, WHICH COINCIDES WITH THE MOST USUAL SITUATION OF FOREIGN BODIES.

To face page 324.

advantage that the patient can readily be examined from a great variety of aspects.

Radiography, on the other hand, affords a permanent picture which possesses a far greater wealth of detail than that shown on the screen, and for this reason it is indispensable in cases where the finer points and differentiations of shadows are required.

Examination with the Röntgen rays is useful in the case of foreign bodies in the larynx where children are concerned, or where inflammatory swelling, œdema, or excessive secretion makes ordinary inspection difficult. In the case of foreign bodies in the trachea or bronchi, the Röntgen examination may afford direct evidence of their presence, or indirect evidence by calling attention to secondary alterations produced by them.

The technique of the application of Röntgen rays in the diagnosis of foreign bodies presents many difficult points, which I have dealt with elsewhere. I will only call attention here to the fact that the skiagraphic presentation of a foreign body depends largely on five factors. (1) Its topographical position, (2) its diameter in the direction of the rays, (3) its specific gravity, (4) its absolute sharpness of outline, (5) its immobility during the examination. In regard to the first point, the position is important in its relation to the shadows seen in the radiogram of a normal thorax—I mean those of the heart, the great vessels, and the ribs. In the case of the second, the intensity of the shadow is proportionate to its diameter. So far as the third is concerned, it may be mentioned, for the sake of those who are unfamiliar with Röntgen-ray work, that, for chemical elements, penetrability to the Röntgen rays is a function of their atomic weight. In the case of the fourth and fifth, sharpness of outline and immobility during the examination are of great importance in the recognition of minute shadow differentiations, as will be seen if account is taken of the varying shadows cast by the heart and great vessels during systole and diastole, and the different degrees of intensity which obtain owing to the relative distance of the various thoracic contents from the photographic plate.

I will now relate a case which shows the use of Röntgen examination, and also emphasizes the extreme difficulties of radiographic interpretation. A young woman had suffered for some time from a slight chronic, but almost feverless, bronchopneumonia of the left lower lobe—circumscribed bronchial breathing, a few rhonchi, slightly increased vocal fremitus, persistent cough, with slight mucous expectoration, which never revealed the presence of tubercle bacilli. Repeated bronchoscopy and probing of the branches in the left lower lobe was without result. A skiagram showed a light shadow in the region of the left cupola of the diaphragm, and this appeared in other skiagrams.

The patient remembered that six months before this she noticed a sharp-edged cavity in a tooth, which led her to suppose that she might have swallowed a piece of filling. Thus the history, the clinical course, and the present condition, gave rise to the supposition of a chronic foreign body in the region of a left lower lobe bronchus. Bronchoscopy and probing so far failed to detect it, but could not absolutely exclude it. The question was how to interpret the evidence of the skiagram. In the differential diagnosis, calcareous nodules on the pleura, and calcareous peribronchial glands, had to be considered. The first have up till now only been seen on the costal pleura in the region of the upper lobe, and can be occluded in the present case by a transverse skiagram, which shows the shadow close up to the vertebral column. I cannot find any case, in the literature, of large calcified bronchial glands in the region of the lung base, and expert radiographers confirm me in the supposition that such a case is unlikely. The skiagram therefore points to the presence of a bronchial foreign body, and to one of considerable diameter, since it could be clearly seen through the heart shadow. It appeared much too big to be contained in the terminal bronchioles in the region of the cupola of the diaphragm. Thus it would seem to be lodged in a branch which ended in the anterior or posterior angle of the diaphragm. The transverse skiagram indicated the posterior angle. But was it not too extensive for this to be the case? In order to decide this point I had a fine wire probe made with a lead end, 2·5 millimetres thick, and passed it into a bronchiole of the third degree, and then had skiagrams taken. At the second attempt the probe lay at a depth of 38½ centimetres in the immediate neighbourhood of, and apparently in contact with, the foreign body, which appeared more than twice as thick as the leaden end of the probe; and thus it was far thicker than the piece of tooth-stopping, and of greater diameter than the bronchioles at this depth. In this connection I must mention, however, that the exposure for the skiagram was 0·1 of a second, which does not entirely exclude an enlargement due to pulsation, and this might not be the case with the probe firmly held above and below. Can it be that the foreign body had pierced the bronchial wall, and owed its increase in size to the formation of concretions around it? The case remains as yet unexplained, but the patient will return at a later date for bronchoscopic treatment. I have related this case, not only on account of its radiographic interest, but also because it affords a typical example of the use of the radiographic probe (Fig. 100).

The limitations of radiography must not, however, be lost sight of. Burger* gives statistics of 100 cases of bronchial foreign bodies, in 78 of which a skiagram showed a positive result. I can only say that this appears an unusually favourable percentage. The value of radiography is best brought out in Killian's series of 164 cases to the end of the year 1907.† If

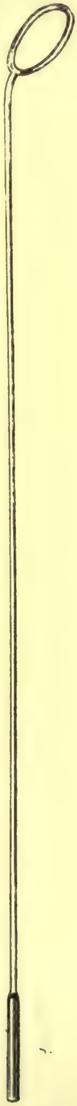

FIG. 100.—RADIOGRAPHIC PROBE, (After Brünings.)

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* *Was leisten die Röntgenstrahlen in der Rhino-Laryngologie?* Bergmann, Wiesbaden, 1908.

† *Zeitschrift für Ohrenheilk., usw.*, Bd. 51.

these are divided into five classes, according to their permeability, the following table is obtained.

I.	Metal objects	51 cases.
II.	Stone, glass, mineral, porcelain objects	9 cases.
III.	Bones, teeth, bone buttons	38 cases.
IV.	Nutshells, cherry-stones, plum-stones, horn, horn buttons, etc.	10 cases.
V.	Pieces of meat or fruit, berries, soft fruit kernels, organic substances ...	56 cases.

This grouping is highly schematic, but it serves to show that the 51 metal objects in Group I. will be certainly recognizable on the photographic plate, while the 56 foreign bodies in Group V. will certainly not be recognizable. Those in Group II. may be considered as generally recognizable, and those in Group IV. as not generally recognizable. Those in Group III. are difficult to determine, but my experience is that, with a good technique, 20 out of the 38 should be recognized. Thus it will be seen that rather less than half of all the foreign bodies are likely to be seen in the skiagram. By means of bronchoscopy at least nine-tenths can be located.

The two methods should, however, not be allowed to compete, but should be used to amplify each other, the skiagram serving as a guide to the future plan of campaign.

Diagnostic bronchoscopy is so closely bound up with therapeutic procedure that I will deal with them both in the next section.

5. Bronchoscopic Extraction.

The treatment of bronchial foreign bodies can only consist in their removal, as, on account of their situation and the functional properties of lung tissue, cure by other means is practically out of the question. As a rule artificial aids are necessary, because spontaneous expulsion only occurs, as has been seen above, in about 33 per cent. of cases involving foreign bodies which are smooth and round, and in about 11 to 12 per cent. of those which are pointed or hollow. In 1,064 cases collected by Preobraschenki and Pohl, spontaneous expulsion occurred in 218--that is to say, in 20·5 per cent.

These figures cannot, however, justify a similar expectation, because delay not only increases the difficulty of extraction, but also militates against the chances of curing symptoms to which the foreign body has given rise. In former times the artificial aids most relied on were the exhibition of expectorants and emetics. The value of these must, however, be regarded as highly questionable, as only 2 to 3 per cent. of cures appear to have been attained in cases where they were used, and even in these instances it is difficult to say that the result was entirely dependent on their exhibition. On numerous occasions it has been recommended that the patient should be inverted or placed head downward, and attempts at displacing the foreign body initiated by slapping him on the back. Reference to the principles underlying the mechanism of the aspiration of the foreign body will show that these methods can have but little value. Where foreign bodies are moving freely in the air-passages, inversion has a very doubtful value. Not only does it hinder the impaction in a bronchus, by means of which the immediate danger is removed, but it also increases the risk of its impaction in the larynx. In the prebronchoscopic period, frequent recourse was had to tracheotomy in order to facilitate the spontaneous expulsion or the instrumental removal of the foreign body. The utility of this procedure is obvious in the case of bodies which are moving freely, and, according to Gottstein's statistics, it is none the less striking that this method brought about spontaneous expulsion in many cases in which round bodies were impacted, whereas it had not the least effect on those which offered but a small surface to the stream of air. In the former case, I suppose, the operation converted an impacted into a "floating" body, and so facilitated its expulsion through the wound. The cough and bronchial catarrh subsequent to tracheotomy may also play their part, as the consequent increase of secretion may lubricate the foreign body. Naturally, blind methods of extraction were freely practised through the tracheotomy wound, and in some cases they were successful, but since the introduction of the endoscopic method they have but little interest. The relative value of tracheotomy itself will be referred to later. There now only remains the consideration of the typical methods, such as endoscopic extraction and operative removal by means of thoracotomy, with or without opening the bronchus. The absolute superiority of the first of these two methods is beyond question, even though von Eicken's series of cases shows 11 per cent. of failures; for Kahler says that, of 291 foreign bodies treated in the last two years, only thirteen (equalling 4·5 per cent.) were unsuccessful, which is a clear proof of the improvement in the technique and in the instrumental equipment.

A discussion of the treatment of foreign bodies will therefore be concerned mainly with a description of the technique of their extraction. This, unfortunately, presents several important difficulties. Personal skill, ingenuity, and mechanical inventive genius, are in this instance of far greater value than a knowledge of definite rules and methods of procedure, as the extraordinary differences in the picture presented by foreign bodies presuppose countless exceptions to ordinary rules of treatment. Success is best obtained by avoiding a too close adherence to any one system, and by the detailed consideration of a great number of concrete cases. A careful examination of such a series will, however, bring to light several general principles which will hold good for the main groups of cases. It is hoped that the value of these in the treatment of bronchial foreign bodies will be apparent from the following pages.

WHEN SHALL BRONCHOSCOPY BE UNDERTAKEN?

That is to say, what is the indication for bronchoscopy for a foreign body, and when is the right moment to apply it?

The first question has already been mainly answered. Examination should be readily undertaken three times too often than once too seldom, since it is usually an absolutely safe procedure, and often the only certain means of obtaining a proper diagnosis. It is now necessary to make some remarks on the proper time to apply the method. One rule always obtains—the chances of extraction are much increased by early bronchoscopy. In cases where the existence of a foreign body is proved or highly probable, the delay of a single night is inadvisable. With foreign bodies which swell, every quarter of an hour is of importance; whilst impacted bodies produce a swelling of the mucous membrane, which increases from hour to hour, and involves the danger of mediastinal emphysema and laryngeal œdema. Pointed objects increase the sensibility in their neighbourhood, and add to the dangers of infection or pneumonia.

The presence of an acute pneumonia is, however, no contraindication for bronchoscopy, as the prognosis depends on the presence of the foreign body, the extraction of which often results in a speedy cure of the lung affection. If tracheotomy has to be performed, the examination is best carried out immediately after the operation, for even on the next day the sensibility and painfulness of the procedure are increased. It is clear that in acute foreign bodies immediate action is the first consideration.

But the necessity for thorough preparation must not be overlooked. Stress must now be laid on cases in which exact clinical observation affords no definite diagnosis, and the question of radioscopy and radiography will need to be considered. The history of the case may definitely prove the nature of the foreign body, and the examination of one similar to that which has been swallowed is often useful. The surgeon must be prepared for every eventuality, and should be provided with efficient assistance and instruments for possible tracheotomy; while care must be taken to see that the tubes, extraction instruments, and every detail of equipment, are in working order.

In cases of chronic foreign bodies any undue haste is to be deprecated. The difficulty of introducing the tube is in these cases often very great, and it is as well gradually to educate the patient to tolerate it. Time may also be required for the devising of special instruments to meet the case. In this connection it may be well to consider the question of the normal duration of a bronchoscopic examination, and of the advisability of its frequent repetition. It is impossible to give a general answer on this point, but certainly one rule always holds good, and that is, that frequent short examinations are far less dangerous for the patient than one that is unduly prolonged.

I have often seen cases in which the surgeon, lured to an excessive keenness by the hope of a successful result, has entirely neglected the general condition of the patient until sudden collapse made it obvious. In children especially, the respiratory centre has a tendency to unexpected and irretrievable failure, and this tendency is undoubtedly increased by carbon dioxide intoxication, repeated application of cocaine, or prolonged anæsthesia. It is a great point in bronchoscopic tactics to know when to stop, so that next day the patient, with fortitude renewed, may be able to assure the attainment of a successful result. The actual time taken by the examination is no criterion, as in one favourable case I was able to diagnose, demonstrate to a colleague, and extract a piece of bone from a main bronchus, within three minutes, whilst another case took Killian and myself ten sittings of more than an hour's duration before an impacted nail could be successfully removed. The danger of bronchoscopy lies in its duration rather than in its repetition. Introduction of the tube for short examination can usually be repeated daily; reactive swelling and inflammation usually necessitate an interval of twenty-four hours, or in children may point to tracheotomy; but this latter question will be considered in the next section.

UPPER OR LOWER METHOD?

The question of the employment of the upper or lower method for bronchial foreign bodies can elicit no general answer.

Two main factors must always be taken into consideration—I mean the skill and experience of the surgeon and the difficulty of the case. In practice a third factor obtains, as the majority of bronchoscopic investigations for foreign bodies are often of a diagnostic nature, because all other methods of examination can, as a rule, only afford a greater or lesser degree of diagnostic probability.

In the clinic, where the lookout for possible foreign bodies is suspected of being unduly keen, the use of the upper method is apt to be pressed unduly. In all cases where there can be a definite diagnosis of a foreign body before the tube is introduced, I would advise beginners to perform tracheotomy in all cases under four years old. It cannot be denied that the slight disadvantages of a primary tracheotomy are certainly outweighed by the certainty of success that the beginner will obtain; and this is more especially the case if the danger of subglottic swelling, the greater use of cocaine, and the prolonged anæsthesia, are taken into account. Statistics show that in the first ten years of bronchoscopy the lower method gained an increasing number of adherents.

Gottstein traced this obvious occurrence to the fact that, with the spread of endoscopy, the ordinary bronchoscopic opportunist lacked the experience that was only to be obtained in the larger clinics.

Since the year 1909, however, there has been, happily, a marked increase in the use of the upper method, which is, I think, in some measure due to the widespread use of the tubes and method of lighting which I have invented. Kahler's statistics show that before 1909 upper bronchoscopy was used in 109 cases out of 233—*i.e.*, in 46·7 per cent.—whereas since 1909 it has been used in 180 cases out of 254—*i.e.*, in 70·8 per cent.

In considering the value of these figures, it must always be borne in mind that the question of the kind of examination comes in, especially in children, since quite half of the bronchoscopic extractions of foreign bodies fall in the first five years of life. Taking these facts into consideration, it would seem likely that since 1909 the lower method was employed in quite half the cases of foreign bodies in children under five years old.

It is possible to arrive at some definite indications, and it would seem that the cases fall mainly into three groups:

1. Cases where a tracheotomy wound already exists, or where tracheotomy is indicated on account of severe dyspnœa.

2. Cases where the foreign bodies are very difficult or dangerous

ones, especially when the patient is not readily amenable to autoscopy.

3. Infants.

Severe dyspnœa of whatever origin is an important relative contra-indication against upper bronchoscopy, as the position of the body necessary for the introduction of the tube, the drag on the tongue and other parts, together with the intense mental uneasiness which is apt to be bound up with the whole procedure, throw so much on the heart and lungs that the method is contra-indicated where these are not quite sound.

The upper method is absolutely contra-indicated in children where the above conditions obtain, and where general anæsthesia is thought to be advisable in addition.

The lower method can be used in high degrees of dyspnœa, especially if this is likely to be benefited by tracheotomy. It is far less disagreeable for the patient, makes it possible to dispense with general anæsthesia, and affords the best chance of using artificial respiration if this should be necessary.

In the second group of cases, where the lower method is indicated, the personal element comes in largely, as the boundary beyond which extraction becomes difficult or dangerous must vary with the surgeon. There are, however, a few definite rules.

It is strongly advisable to perform preliminary tracheotomy in all cases where the foreign body is moving up and down in the air-passages, especially where children are concerned. The patient usually comes for treatment in an exhausted and highly irritable condition, and the foreign body is often so large as to preclude the possibility of ordinary extraction, owing to the reactionary swelling of the subglottic space. After tracheotomy the foreign body may be coughed out, without even employing a bronchoscope, if the edges of the tracheotomy wound are held apart by retractors. This manœuvre is not, however, free from danger. I once had a case of movable foreign body—an unripe gooseberry—in which I performed tracheotomy, and waited for the next fit of coughing to expel it into the wound. This happened, but, owing to some swelling of the mucosa, the gooseberry became impacted in the bottom of the wound. A hurried attempt at extraction with the usual toothed forceps was unavailing, although the object was clearly visible, and nothing remained but to push it down again into the trachea. With the next inspiration it stuck fast in the main bronchus, and almost proved fatal to the child, who was already much collapsed. Fortunately, a rapid extraction through a bronchoscope, followed by artificial respiration, prevented disaster.

Another misfortune that may occur is that the foreign body might be aspirated into the bronchus which serves the healthy lung when the other lung is temporarily collapsed, owing to the prolonged presence of the foreign body in its bronchus.

I mention this case to add point to the warning that, before attempting extraction, tracheotomy instruments should be always at hand, and, conversely, tracheotomy for a foreign body should not be undertaken unless the endoscopic tubes, electroscope, and forceps, are ready for immediate use.

Any case of primary impaction in a main bronchus may be classed as difficult and dangerous, more especially an object such as a gooseberry is by no means easy to catch hold of, and, owing to its shape and size, can readily occlude a main bronchus. The dangerous nature of this class of body, of which beans are the worst example, lies in the capacity to complete occlusion of the main bronchus, and consequent limitation of function in the lung on that side. In children this may result in complete collapse of the lung, even within twenty-four hours; there may be no obvious dyspnœa if the child is quiet, and the lung soon regains its function if the foreign body is removed.

If such a foreign body becomes dislodged, either spontaneously or during attempts at extraction, there is a great danger that it may be re-aspirated into the bronchus on the sound side, as the suction in this direction will necessarily be much increased. I have seen a highly skilled bronchoscopist, with every resource at his disposal, lose an apparently healthy child from this very occurrence, and this accident is by no means unique in the literature of bronchoscopy.

When a foreign body has caused any lung insufficiency on one side, the surgeon must proceed with the greatest foresight. If the object is one that can be easily and firmly held by the forceps, there is no contra-indication to the upper method, but smooth round objects or those that are friable should only be attempted through a tracheotomy wound. Von Eicken was the first to call attention to this source of danger, and has, especially in the case of beans, strongly advised the use of the lower method, as with this the danger of slipping off is very slight, and the tube can, if necessary, be reintroduced in a few seconds. I readily endorse this opinion, and for less practised observers would extend it to cover a wider range than beans. In this connection I have had a small piece of apparatus constructed, which may in the future do something to diminish the need for tracheotomy in these cases.

The principle underlying it is to diminish the danger of re-aspiration into the bronchus on the sound side by shutting this off by means of a filigree which will not hinder breathing. Such an apparatus, for this reason, must be capable of being introduced and removed easily, and yet be sieve-like and self-retaining. I think that my bronchial protector solves the main difficulties. It consists of a small bottle-brush, whose spiral wire ends at either side in a closed wire hook. The bristles are arranged close enough to insure the action of a sieve. I have had them made of different lengths and in four diameters, as follows: For children up to two years, 8 millimetres; for children from three to six years, 10 millimetres; for children from six to twelve years, 12 millimetres; and for adults, 15 millimetres. The protector can be readily introduced with the ordinary claw forceps through the bronchoscopic tube. It is not necessary to insert the tube itself right into the healthy bronchus, as after the tube end has passed the bifurcation the protector can be pushed into the desired position. The splaying out of the bristles enables the protector to remain in position even during coughing, and the extraction can then be proceeded with. The objection to the method is that, after successful extraction, the forceps must be introduced again to remove the protector, but this is very easily done. In order to do away with this second introduction, a piece of fine silk may be tied on the upper ring of the protector which can be drawn out by this means. This may not, however, do away with the necessity for a second introduction in all cases, as the thread is apt to be broken while the foreign body is being extracted. For skilled bronchoscopists this procedure will, in my opinion, not mean the abandonment of the use of the bronchial protector or of tracheotomy, while in the case of beginners—who should never be reproached for employing tracheotomy—I hold it advisable to employ the protector even with the lower method, as it prevents any chance of re-aspiration into the healthy bronchus. So far I have only used this small piece of apparatus experimentally on practised patients, but it seems to answer all requirements, and I should advise its being kept ready for cases of foreign bodies. After what has been said, I need scarcely mention that to the class of difficult and dangerous foreign bodies belong large sharp or pointed objects, such as dentures, pieces of glass, buckles, etc. In attempting the extraction of these *per vias naturales*, the larynx is easily damaged, and it is better to employ the lower method. I would also point out that chronic foreign bodies behind bronchial stenoses present very great difficulties, and often a great number of sittings are necessary before success is attained. The presence of a tracheotomy wound is a great advantage both for the surgeon and for the patient, as operative measures can be more surely executed, can be of longer duration, and can be repeated more quickly. I have mentioned as the third indication for lower bronchoscopy foreign bodies in infants, and I know that on this point I am at variance with many. Neumayer has extracted foreign bodies from children of six and a half and nine and a half months old by the upper method, and I have myself done so, but I do not advise the use of this method by any but the most skilled workers. The narrowest tube in my equipment has an outside diameter of 7 to 7½ millimetres, and cannot be passed through a child's larynx without danger before it is one year old, whilst I hold that the routine use of narrower tubes is inadvisable owing to the uncertainty of lighting and the lack of room. The practice of the most skilled observers should not be taken as a criterion, and, after long experience, I would advise the less practised worker usually to perform tracheotomy for foreign bodies in children under two years of age. It is not only necessary to introduce the tube into the bronchial tree, but also to perform the extraction as quickly as possible, as the subglottic space of children will not tolerate much pressure without considerable reactive swelling. I extracted by the upper method a walnut-shell from the bronchus of a girl who was one and a half years old, and was misguided enough to extend the duration of introduction of the tube, for purposes of demonstration, to almost half an hour. The result was severe subglottic swelling, which necessitated intubation the next day. Eight days afterwards there were signs of perilaryngeal inflammation, and it was impossible to leave the tube out for more than an hour. A low tracheotomy was performed, and when the inflammation subsided there was an almost complete subglottic scar stenosis, which took more than a year's treatment to cure. Similar cases are by no means rare in the literature, and point strongly to the inadvisability of forced or prolonged upper bronchoscopy in infants. In every case preparation should be made for tracheotomy. The intubation-tube should never be employed, as it only increases the reactive swelling. I would also advise beginners not to push the more elegant upper method unwarrantably; and if success in small children is not attained in a quarter of an hour, the trachea should be opened without more ado.

High tracheotomy suffices for bronchoscopic needs, and the increased distance from the object is negligible with modern instruments, whereas the deep rigid wound of a low tracheotomy affords a greater danger of surgical emphysema, and should be avoided.

THE TECHNIQUE OF NORMAL EXTRACTION.

The ordinary normal extraction of a foreign body requires two conditions for the surgeon—*i.e.*, complete immobility and slight mechanical dexterity. The former is by far the more important as the purely mechanical part is, as a rule, easier than the extraction of a foreign body from the nose or the ear. Practice, however, even on the dummy, is not to be despised, and increases the certainty of result when the surgeon is brought face to face with his first foreign body in the living patient. It is specially valuable for the recognition of the foreign body. Under normal conditions it is quite impossible to miss a foreign body in the main bronchus. Frequently it is seen during autoscopy, or a slight inflammatory reddening is observed on one side of the bifurcation, and when the tube spatula is pushed into the trachea, the object itself comes into view in the distance. It only remains to localize it, cocainize it, and extract it. The cocainization of the surrounding parts is generally not necessary when the object has been recently aspirated, especially if the surgeon is fairly certain that he can get hold of it at the first attempt. If, however, there is any surrounding inflammation, or any delicate manipulation is likely to be required (as in the case of needles or beans), it is advisable to proceed carefully to apply adrenalin and cocaine to the neighbourhood of the foreign body. This can usually be done by means of a steel wool-carrier, which is pushed beyond the end of the tube, but not so far as to disturb the foreign body. It must not be too small, and should be soaked with adrenalin and cocaine, and firmly applied to the bronchial wall. A more certain way is to employ the medium-length canula of my painting syringe, and drop the cocaine from this. With acute foreign bodies special cleaning of the field of vision can seldom be dispensed with. In chronic cases the object must, as far as possible, be freed from mucus and pus until its shape and situation and the condition of the bronchial wall can be determined with certainty. This cleansing should be performed with the greatest caution, and after a thorough use of the cocaine and adrenalin solution. Caution is necessary, not only on account of the danger of pushing the foreign body farther down, but also because of the tendency to produce bleeding of the bronchial mucosa. A slight staining of the mucus with blood is sufficient to obscure the entire field of operation, as the dark red colour produced reflects but few rays of the endoscopic light. I have already mentioned the method of employing the forceps, and have called attention to the need for assistance. The selection of end-pieces for the forceps has already been discussed, but when the operator is in doubt which to use, I should advise him to rely on the claw forceps. A successful result will usually be obtained in 90 per cent. of the cases at the first attempt.

It is now time to consider the question how near the foreign body it is advisable to push the tube. This largely depends on the nature of the foreign body. When this is a simple one which can easily be caught hold of, such as a newly aspirated piece of bone, it is often sufficient to obtain a tracheoscopic view of the object, and to pass the forceps from the trachea into the bronchus, and so secure the object. Round impacted objects usually require a correct presentation of the lumen, with the end of the tube far enough from the object to allow the end-piece of the forceps to expand to the width of the bronchus and so to seize the foreign body at its greatest circumference. With needles and other pointed objects, manipulation should be such that the dangerous point may lie within the tube. All these rules, however, are merely relative. For instance, where a bean is obstructing the main bronchus, the tube may be pressed against the lateral wall just above it, so as to make a cleft through which a hook may be passed beyond it. Needles which are impacted with their points upwards can often be dislodged by a hook when the end of the tube is some distance off, and this can then be pushed down and the object safely extracted.

Which is the best way to take hold of a foreign body? On no account should any force be employed, as the normal extraction of a foreign body requires no exercise of force. Such bodies are usually so slightly impacted that, when the tube has stretched the bronchial wall above them, a powerful cough will often expel them. My bronchoscopic forceps are constructed for delicate and skilful manipulation, and not for a trial of strength, by which, indeed, either they or the foreign body are likely to be broken. Moreover, the employment of force diminishes the tactile sensibility which is so important to success.

The guidance of the eye does not usually suffice for the majority of foreign bodies in children, and success often depends on a combination of sight and touch. If the object has been accurately "presented," so that the part to be caught hold of lies exactly below the end of the tube, the closed forceps may be gently pushed down to it. Owing to perspective foreshortening, it is difficult to estimate exactly where the end of the forceps is, and great care must be used as the foreign body is approached. Tactile impressions are often very helpful.

The forceps may be used closed, like a probe, and when the object is lightly touched it can be opened and pushed past it, or they can be used open and pushed gradually towards the object. The latter method is usual when the foreign body is small and soft.

I have often noticed that the beginner is very timid when using the forceps, for fear of pushing the object farther down. The danger of this is not as great as is usually supposed. When the object is impacted in the main airway or at a point of bifurcation, it can be touched with impunity, and round objects which are obstructing a bronchus often require the use of considerable pressure before the forceps can be got past them. It does not matter if they slip downwards a little; it is, indeed, often easier to extract them from the new position, as the mucosa is not so inflamed.

When the smallest-sized tubes are being used, the eye can only enable the recognition and presentation of the object to be effected; the rest must be done by touch.

The next point to be considered is the method of extraction.

In the majority of cases the object is not extracted through the tube, but at the end of it. Before withdrawing the tube it is important to determine whether the object is closely following the tube, and whether the forceps is holding it really fast.

These points can often only be determined by tactile impressions, and it is sometimes difficult to say whether the object is in the forceps or not. As a rule, when the forceps is closed, the sense of something in it is obtained, and when it is withdrawn a slight resistance may be felt. The surest guide is when the foreign body is carefully drawn up and touches the end of the tube. I rely mainly on this device, as it also affords evidence of the firmness with which the forceps is holding the object. If this slips off, or a piece of it breaks off when the tube is touched, it is better to get a fresh hold of it, as this is far easier to do than if the object becomes impacted in the larynx, or is re-aspirated, and makes a fresh introduction of the tube necessary. Two methods of withdrawing the foreign body at the end of the tube are commonly employed. The bronchoscopic tube is withdrawn slowly and steadily, the foreign body being kept in contact with its end, or else the tube and forceps is each drawn out alternately a few centimetres at a time. In both cases the extraction is performed as far as possible under ocular control, as by this means any untoward movement of the foreign body can be observed.

Personally I employ the second method, as I think that the alternate withdrawal of the tube and forceps enables the extraction to be performed more delicately. Pieces of bone, nutshells, and the like, are readily extracted by either method.

The most important moment in the extraction is during the passage of the larynx. It is not advisable at this point to allow the tube to follow passively the natural bends of the air-passages, as the end of the tube would press against the posterior laryngeal wall. The tube should be firmly under control, and should be kept exactly in the middle of the airway, as only by this means can the larynx be safely passed without the exercise of considerable lateral pressure. The danger of the foreign body becoming detached by rubbing against the sides of the passage occurs mainly above the larynx, and in this situation its occurrence is not so important.

In conclusion I would urge that the recognition, presentation, fixation, and extraction of the foreign body should be performed with the greatest patience, circumspection, and delicacy of touch, and the surgeon who does not naturally possess these gifts should aim at acquiring them.

I will now turn to the consideration of the extent of a bronchoscopic examination for a foreign body. Approaching the matter from the diagnostic side, it may be said that the presence of a foreign body cannot be excluded until both bronchi have been explored as far as the point where the lower lobe branches are given off.

In this connection I can recall a case in which the history and symptoms pointed to the probability of a foreign body occluding the right main bronchus. Bronchoscopy showed a marked inflammation of the mucosa in this situation, but no trace of a foreign body could be seen in the right side. It would appear, therefore, that it had been coughed out just before the introduction of the tube, perhaps during cocainization. During the night mediastinal emphysema supervened, and a further bronchoscopic examination showed the foreign body (a nut kernel) in the left main bronchus, into which it had doubtless slipped during the previous bronchoscopic manipulation. The rule that the presence of a foreign body can be excluded after a systematic inspection of both main bronchi and their chief subdivisions holds good for large objects. There are exceptions which call for the use of other diagnostic aids which will be discussed later. On the therapeutic side, bronchoscopy cannot be regarded as satisfactorily completed until the foreign body has been entirely removed. Primary multiple foreign bodies rarely occur, and the surgeon should aim at complete removal of the foreign body with a single introduction of the tube. In some cases fragments have to be dealt with, such as pieces of fruit kernels or bits of food. A firm hold with the forceps is the best guard against fragmentation during extraction. If the object is very friable, the tube should be introduced after extraction to make certain that nothing has been left behind. When the object is broken by clumsy efforts to seize it with the forceps, it is well to look carefully for fragments in both main bronchi. As a rule it is sufficient to extract fragments which are bigger than the head of a match one by one through the tube. Fragments smaller than this cannot be considered as quite harmless, but they are generally coughed up. Every other means should be tried before an impacted friable object is broken up *in situ* to facilitate extraction.

In the after-treatment of foreign body cases, bronchoscopy is only used for scar tissue stenoses. Wounds of the mucosa, ulcers, and granulations, soon disappear. I have seen even stenoses of more than a month's duration gradually disappear after the extraction of the foreign body, and leave only the slightest alteration in the diameter of the bronchus.

Touching the damaged mucosa with 5 per cent. silver nitrate quickens the healing; but this can be dispensed with, and I only recommend its use when the tube has to be introduced for other reasons.

SPECIAL METHODS OF EXTRACTION.

The method which has just been described applies only to "normal" cases. These number about 70 per cent. of the whole, so that there remain 30 per cent. of cases, in which some special devices must be employed.

The necessity for these is to be found in—

1. The peculiarity of the foreign body (beans, collar-studs, open safety-pins, etc.).
2. The position of the foreign body (smaller bronchioles).
3. Alterations of the bronchial wall (stenoses).

Concerning the first group, I have already mentioned the frequency with which beans occur, and the dangers and difficulties of their extraction. Re-aspiration into the bronchus on the sound side may be prevented by the use of my "bronchial protector," and delicate manipulation of the instruments will do much to avoid fragmentation of the object.

The claw forceps is most useful, as it can grip firmly even the top of the bean, provided that this is not too swollen and friable. If the forceps is of no avail, hooks, galvano-cautery drills, saws, and bean feathers, may be tried. The blunt hook is supplied in my "set," and should be tried first. Success is often obtained by pressing on the lateral wall of the bronchus and slipping the hook past the bean. In other cases a patient and wearisome attempt must be made to engage some furrow on the surface of the bean.

There appear to be great possibilities in the careful use of the galvano-cautery point, as this takes firm hold of moist objects. I have employed one with a cross-shaped end with great success on the dummy; it is similar to Gottstein's, but has some advantages over it.

In using the galvano-cautery, the bronchoscopic tube must be pushed right down to the foreign body, and the wire should only be allowed to glow intermittently so as to avoid any undue heat.

For dealing with beans I have had one or two instruments constructed which seem to me likely to be extremely useful, although up till now they have only been employed on the dummy. They may be called a "bean feather," a "bean saw," and a "bean borer."

The bean feather (Fig. 101) consists of a very fine steel wire brush, the bristles of which are directed upwards like those of a quill. It is only a fraction of a millimetre thick, and can be passed through the smallest chink. When this is drawn back the bristles stand on end, stick in the softened bean, and draw it out with them.

The bean saw (Fig. 102) aims at loosening or, if this is impossible, at dividing the impacted bean. Its diameter is also small, and so it is easily passed. The blunt teeth can readily be applied to the bean and saw it in two.

The bean borer (Fig. 103) is designed to make a hole in the foreign body, if it is found impossible to get any instrument past it. It has a short, pointed steel end bent at an angle, so that the boring can be done under guidance of the eye, and any possibility of wounding the bronchial wall is avoided. When a hole of sufficient depth has been bored in the bean, it may be possible to obtain an adequate hold with the claw forceps. A further manœuvre, recommended by Thost,* consists in glueing or cementing the bean with sealing-wax or shellac. I cannot, however, think that this procedure has anything to recommend it.

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* *Monatsschr. f. Ohrenheilk.*, 1905, S. 153.

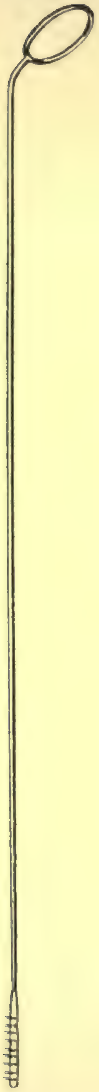


FIG. 101.—BEAN FEATHER. (After Brünings.)

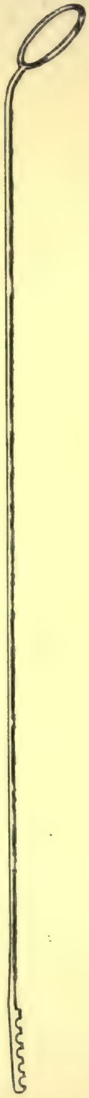


FIG. 102.—BEAN SAW. (After Brünings.)

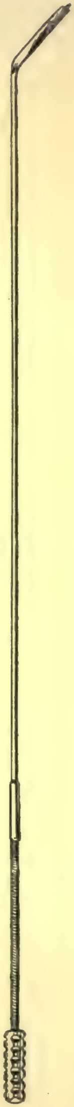


FIG. 103.—BEAN BORER. (After Brünings.)

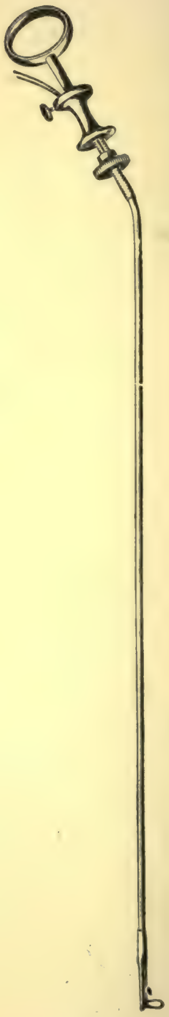


FIG. 104.—LOOP EXTRACTOR.

There are already quite a number of similar cases in the literature, in the majority of which extraction was not accomplished. I have therefore had a special collar-stud extractor made, the lower blade of which can be opened very wide and consists of a fine hook which can readily be pushed obliquely past the head of the collar-stud (Fig. 105). The instrument takes a very firm hold of the object, as is most important in such cases. Mention must also be made of my loop extractor, which is a bronchoscopic snare the wire of which runs through two small holes placed at the sides of the flattened end of the tube, so that the loop works perpendicularly to the axis of the tube. The instrument (Fig. 104) is useful for the extraction of needles, nails, and similar bodies, which usually lie more or less obliquely across the bronchial tube. A snare of this construction has this advantage over other grasping forceps, that, as it catches hold of an obliquely-placed needle, it tends to bring its long axis parallel to that of the tube, and so prevents the possibility of its catching on the side during extraction. It is obvious that the loop extractor is especially useful when the seizing of the object cannot be performed under accurate guidance of the eye on account of excessive secretion or narrowness of the passage. In some cases successful results have been obtained through tactile sensation alone. The loop is made as large as the diameter of the bronchus will warrant, so that, as it is pushed down, the foreign body will be with certainty included in it. As the loop extractor is extremely delicate and at the same time powerful, it will serve for the extraction or removal of many other objects. For the removal of portions of tissue from the bronchial wall the double curette of my normal instrumentarium does not always suffice. In such cases a cutting punch forceps, which works in a vertical direction like that for the larynx, will be found

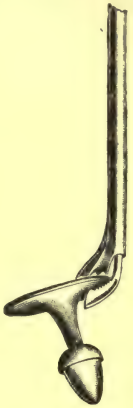


FIG. 105.—COLLAR-STUD FORCEPS. (After Brünings.)

useful. Von Eicken had one made for the removal of an enchondroma of the bronchus, and employed it with success. In addition to these instruments a great number of special instruments have been devised, especially in America, to meet the case of rare bronchoscopic conditions. I cannot enter into their various practical merits, but would refer the reader to the report of the Third International Laryngological Congress held at Berlin in 1911, in which a good, though uncritical, review of the more modern instruments is to be found. At this point I think it will be well to devote a few words to special methods of extraction, the advantages of which do not seem to be well understood. It is necessary to consider the use of positive or negative air-pressure and electro-magnets. Many authors do not mention them at all; and although I consider them of but little use, I will pass them shortly in review to reveal their weakness. A foreign body can be removed by aspiration in two ways.

If it completely obstructs the bronchus, it would be possible to pass an air-tight bronchoscope down to it without disturbing it. If the tube is exhausted, the foreign body should be sucked in—that is to say, it would be sucked in if the bronchial tree was completely rigid. But this is not the case, and the bronchial wall is sucked in just as much as the foreign body, and its lateral pressure holds the foreign body immovable. The other manœuvre consists in passing the aspirating-tube right over the foreign body. A complete vacuum could seldom be hoped for, and so it would at least be desirable to fit the end of the tube with a short piece of rubber in order to increase the chances of air-tight adaptation. How could this procedure provide sufficient force for extraction? If, for instance, there is a bean in a child's bronchus down to which an 8-millimetre tube (7-millimetre lumen) could be brought, a space of at least 1 millimetre must be left between the tube wall and that of the aspirating-tube. Now, the wall of the aspirating-tube is also 1 millimetre thick so that there remains a diameter of about 6 millimetres in which a relative vacuum of half an atmosphere exerts a pull of about 33 grammes. In practice not even this small amount of energy would come into play, as the foreign body would be somewhat held back on one side or the other, and would exert some leverage on the end of the tube which might easily result in its separation from it. The only point in favour of pneumatic extraction or expulsion seems to me to have been made by Gottstein. He recommends that a hollow hook should be pushed past the obstructing foreign body, and air blown into the bronchus behind it; but even the value of this appears doubtful, as the air-pressure only acts on the inner wall of the bronchus, and would tend to dilate it. Moreover, the main difficulty of extracting obstructing foreign bodies is bound up with this very manœuvre of pushing a hook past them. If this was successfully accomplished, the small stream of air which could come from a fine hollow hook would seem to me to have no difficulty in getting past the foreign body itself.

On these grounds I would advise against all methods depending on aspiration so long as there is any possibility of extraction by other means, not excluding galvano-cautery and the breaking up of the foreign body.

I am afraid that my experience of magnetic extraction is no better. In the first place, very few foreign bodies are made of steel or of iron, and in the case of these magnetic extraction has one special danger. As a rule foreign bodies such as needles or nails are apt to lie more or less vertically, while all magnets have the property of pulling vertical objects perpendicularly to the line of force—that is, across the axis of the magnet—so that an attempted extraction by this means might easily result in the end of the needle sticking in the wall of the bronchus.

The second point that has been mentioned—namely, the difficulty of treating foreign bodies in bronchi which are small or difficult of access—must now be considered, although for practical purposes it plays a smaller part than might be thought likely. In the large side-bronchi, the right stem bronchus, and the right upper and middle lobe bronchus, foreign bodies are very rarely seen. The direction of these bronchi is mainly horizontal, and in some cases ascending, so that they are out of the path of a foreign body, and are only invaded by some special accident.

In this connection it can, fortunately, be noted that as a rule the path that the foreign body takes, and the possibility of reaching it bronchoscopically, are mutually interdependent. The difficulty is relatively greater in the bronchioles of the lower lobe, which coincide more or less with the path of the foreign body. The bronchoscopic recognition of such unusual foreign bodies can provide in the acute stage very great difficulties, as direct inspection of the large side-bronchi can only be obtained to a limited degreee. It should be remembered that the side-bronchi can be much more readily and thoroughly inspected by lower bronchoscopy than by the upper method. A complete inspection can only be obtained by using special instruments which are constructed on the cystoscopic plan.

In the territory of the lower lobe an inspection of the secondary bronchi is possible without any special instruments, so long as they do not deviate too much from the direction of the main bronchus. The procedure is similar to that for the presentation of a main bronchus by means of a tracheoscopic tube. This is pushed as near as possible to the point of bifurcation, and inclined so that the bronchiole which is to be examined, but which is too small for the tube to enter, coincides with the direction of the tube. By this means not only the secondary bronchi but also the points where they bifurcate into those of the third degree can frequently be inspected, and in a few particularly favourable cases the tertiary bronchi may occasionally be brought into view. A more certain method than this indirect presentation consists in an inspection through tubes of a very narrow calibre, which can be directly inserted into the bronchioles. From the point of view of illumination it is advisable that such tubes should not be narrow in their whole length, but should have a narrow end a few centimetres long attached to them. This is best applied in the form of a short extension tube, as Killian has suggested. I had previously had made special conical inner tubes for my ordinary bronchoscope, but the desired result was only incompletely attained by this method. The wide part of the double tube should be long enough to allow of the bifurcation of the lower lobe branches being presented, so that their number and position can be accurately estimated, as is only possible with a large field of vision.

If it is desired to examine any one of these, it must be accurately presented, and the short narrow extension-tube pushed into it. To attain this object I have had a special tube made, which has proved extremely useful in two cases. It is made in three sizes, to fit my tubes of 12, 10, and 8·5 millimetres diameter. The lumen of the conical extension-tubes measures 7, 6, and 5 millimetres. It is quite possible with these tubes to obtain an accurate lumen presentation of the tertiary bronchi in systematic order. In cases of chronic foreign bodies which declare themselves some time after their aspiration, local swelling of the mucosa and increased secretion afford a certain guide for localization, which renders unnecessary the tiresome and exhausting systematic examination of the whole lower lobe. The purulent bronchitis which accompanies such foreign bodies undoubtedly increases the difficulties of the presentation of the object, as the small field of vision is not stationary, while white masses of mucus, dark blood-clots, or bright points of bifurcation simulate foreign bodies or conceal those that may be present. In such cases great reliance must be placed on the probe, and Killian has strongly recommended the palpatory exploration of the peripheral regions of the lung. The majority of foreign bodies which occur in narrow bronchi are usually hard substances, which are clearly perceptible to the touch. Moreover, the probe can reach much farther towards the base of the lungs than the sight can penetrate. It is obvious that the extraction of such peripheral foreign bodies is very difficult. The procedure is entirely dependent on tactile sensibility, and reliance must chiefly be placed on the claw forceps, as this can work in a narrow passage and grip with certainty. It cannot be denied that, with this blind method, it is easy to engage a point of bifurcation in the forceps. When this is the case, a characteristic elastic resistance will be experienced when the forceps is pulled. The forceps should then be disengaged, and introduced again in a slightly different direction.

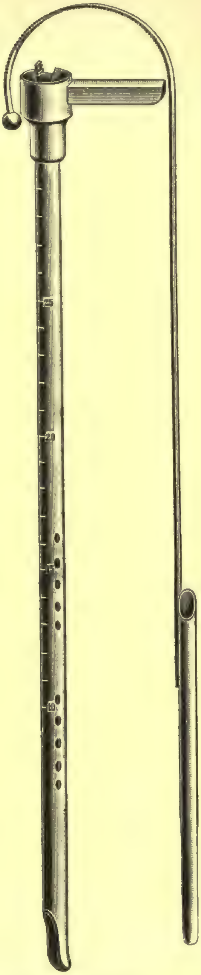


Fig. 106.—Special Tube for Bronchioles of Finer Degree.

If the foreign body is of iron or steel, an electro-magnet might possibly be of use. Fortunately, as I have often said, foreign bodies in the peripheral bronchi are extremely rare. They are almost beyond the limits within which bronchoscopy can be employed, and for this reason approach an area in which surgical measures have an increasing chance of being successfully undertaken.

The third group of cases which require special therapeutic measures are those in which foreign bodies occur behind bronchial stenoses. Consideration of the pathology of foreign bodies has shown that all foreign bodies which occasion destructive processes in the neighbouring bronchial wall must eventually lead to the formation of scar stenoses. It is characteristic of these stenoses that they almost always occur above the foreign body, while the latter often lies in a bronchiectatic cavity. If the cases have occasioned purulent bronchitis of years' duration, the bronchiectasis may involve the whole of the lung which has been shut off, and this is converted into a honeycomb of expanded loculi which have completely lost all trace of respiratory epithelium. The underlying cause appears to be due not so much to the chronic cough as to the continued pressure and irritation of the stagnant secretion. This is, owing to the upright position, largely retained, as the stenosis prevents the cavity being properly emptied, while the destruction of the ciliated epithelium, the atelectasis, and the inflammatory induration of the surrounding lung tissue renders efficient expectoration impossible. The bronchoscopic extraction of a foreign body behind a scar tissue stenosis is not only complicated by this condition, but is also made difficult by the persistent cough and the profuse secretion. How difficult this can be may be illustrated by a case, often referred to, which I treated in conjunction with Killian. As it affords a typical example of the technique required, a detailed consideration of it will be useful.

The patient, who was thirty-five years old, aspirated a carpet nail during an epileptic attack, but the diagnosis was only definitely made five years after the occurrence by means of a skiagram, although the patient had spent some years in sanatoria on account of severe affection of the lung. He was afflicted with incessant cough by day and night, and daily brought up quantities of stinking pus. This excessive irritation of the air-passages, which maximal doses of codein and the use of cocaine in almost fatal quantities did little to relieve, made the introduction of the bronchoscopic tube almost impossible. The preliminary measure which afforded the best preparation for the endoscopic examination was the following. For some hours before the examination the patient was laid either in a horizontal position or with the upper part of the body somewhat dependent, the affected lung being uppermost. The bronchiectatic secretion was thus enabled to flow against the stenosis, and was freely expectorated at every cough. In spite of this preparation, most of the time of the bronchoscopic examination, which often lasted one or two hours, was lost, owing to the cleansing of the field of vision, of the tubes, of the electroscopic mirror, and of the spectacles which the surgeon was compelled to wear. At last in the right main bronchus subserving the upper lobe a funnel-shaped stenosis was observed, in the lumen of which the shank of the nail was impacted. The condition turned out to be of the character illustrated in the sketch which forms Fig. 107. Attempts to get hold of the shank of the nail proved fruitless although I had numerous special gripping forceps constructed for the purpose. It became obvious that a preliminary systematic dilatation of the stenosis must be undertaken. The question was how best to effect this dilatation. Active removal, caustics, or electrolysis, could scarcely be considered, as such scar stenoses are not

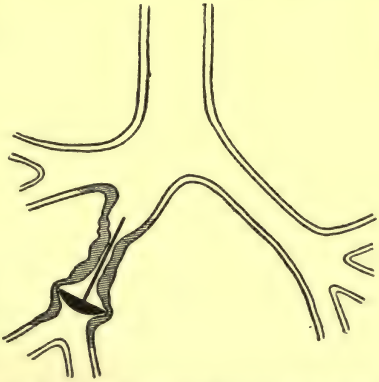


FIG. 107.—NAIL IN STENOSIS OF RIGHT MAIN BRONCHUS.

dependent only on the formation of new tissue, but are partially formed by a crumpling of the collapsed bronchial wall. A widening by means of tissue removal would not be without danger; and even if a successful extraction should result, it would be followed by a more excessive formation of scar tissue. The only method that seemed at all practical was some form of stretching by means of blunt instruments, and this presented many points of difficulty. The first attempt showed that the passage of a bougie in the neighbourhood of the foreign body was useless. The accompanying figure (Fig. 108) shows that such a procedure is not without danger, as either the point of the nail (*b*) or its head (*c*) must make way for the bougie, and so endanger the bronchial wall.

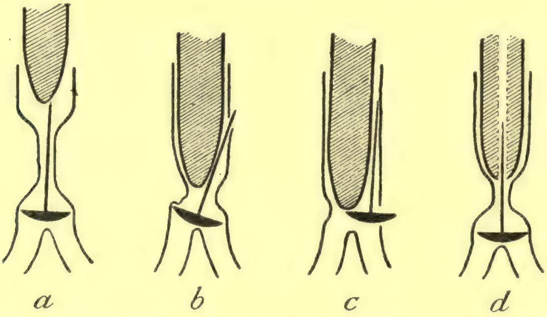


FIG. 108.—EXCENTRIC (*a, b, c*) AND CONCENTRIC (*d*) BOUGIEING.

Eventually I had a concentric metal bougie made (Fig. 109)—that is to say, a thin-walled tube with an olive-shaped end which had a central hole.

This bougie, which is accurately graduated in millimetres, serves for every kind of treatment in bronchial stenosis. In cases of foreign bodies it can be used in conjunction with my special extraction instruments.

For foreign bodies these can be used with advantage in conjunction with my handleless extraction instruments, which are fitted with the ordinary types of end-piece. The closing of the forceps is not brought about by traction on the ordinary ring handle, but is dependent on a simple mechanical arrangement, shown in Fig. 110, which involves the use of a small pliers. After the foreign body has been firmly gripped the pliers is taken off. The concentric metal bougie can then be pushed over the handleless forceps, which, owing to the special closing mechanism, has a uniform diameter of only 4 millimetres. The advantage of this method is that the foreign body can be firmly held during the bougieing, and cannot slip farther down, and it is quite possible to extract it in close contact with the end of the thickest bougie that it has been possible to insert. This point is extremely important, as scar tissue stenoses have the property that, as soon as the bougie has been withdrawn, elastic contraction causes a subsequent narrowing in a few seconds. There is not, therefore, time, after dilatation has been accomplished, to introduce an ordinary bronchoscopic tube, and to attempt to engage the foreign body with the usual type of forceps. In the present case concentric bougieing over the handleless forceps was tried at many sittings, but was not successful, chiefly, I think, on two grounds. In the first place, every bougie which can only be passed down to the top of the foreign body, on account of its conical end, leaves a circular ledge of stenosing tissue, as is indicated in the accompanying sketch (Fig. 111). It is almost impossible by means of simple bougieing to dilate a bronchus to its normal width. The stenosis can only be stretched, in the most favourable cases, to a diameter equal to that of the bronchus itself, and when the bougie is withdrawn elastic recoil causes the stenosis to project somewhat into the lumen. This property is extremely important in considering the extraction of foreign bodies, as they frequently occupy the whole circumference of the lumen. In this case it was not possible, for these reasons, to draw

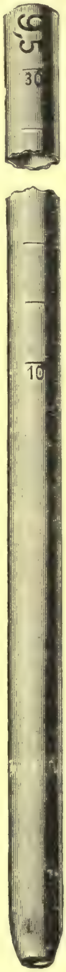


Fig. 109.—Concentric Metal Bougie.

the large head of the nail through the stenosis in close contact with the end of the thickest bougie, although a loop extractor was firmly fixed on the shank and it was possible to pull with considerable force. I had to construct a special dilating instrument which was capable of fulfilling three main requirements. It had (1) to have an end which was not conical, but completely cylindrical; (2) to expand wider than the normal bronchial lumen; (3) to allow the passage of instruments through it. These requirements were obtained in the bronchoscopic extraction dilator which is shown in Fig. 112. It consists of a bronchoscopic tube, the lower end of which (*b*) terminates in a number of conically thickened flanges. Into this tube a thin inner tube can be pushed, which causes the flanges to spread out as in (*c*). The pushing down of the inner tube is brought about by a screw mechanism (*d*) placed at the upper end. This is graduated, and the diameter of spread can be read in centimetres on the scale (*e*). The use of this instrument at last enabled us to reach a successful issue in the case in the following manner: The shank of the nail was first firmly engaged in a handleless loop extractor, and pushed downwards a short distance from the stenosis. After concentric bougieing it was possible to push the blunt 8-millimetre end of the closed extraction dilator over the gripping instrument right

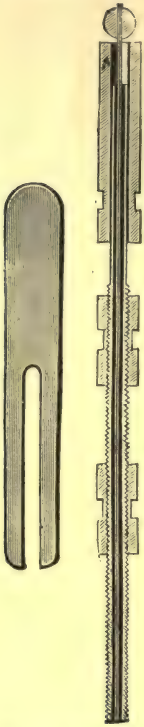
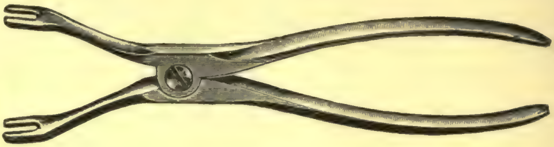


FIG. 110. — MECHANISM ILLUSTRATING HANDLELESS EXTRACTION INSTRUMENT.



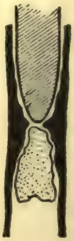


FIG. 111.— FOREIGN BODY BEHIND STENOSIS.

through the stenosis. The nail was then drawn upwards until its head was seen clearly to lie against the straight end of the extraction dilator, while the shank projected into the tube. The spreading of the end was then carefully undertaken up to 9, 10, 11 millimetres, and at each of these points extraction was attempted. It was not until the spread had reached a diameter of more than 12 millimetres that it was possible, by using considerable force, to draw the nail through the stenosis. The nail was observed to occupy the position with its broad sharp-edged top within and covered by the outspread end of the dilator. Although this case is a special one, it points out many important rules which are generally applicable in the treatment of foreign bodies behind bronchial stenoses. In the first place, it is noteworthy that it is possible, by systematic procedure, to dilate an old scar tissue stenosis of about 2 millimetres diameter to a width of more than 12 millimetres—that is, more than six times its original width. It must, however, be remembered that this dilatation is by no means a permanent one. As soon as the bougie was withdrawn, elastic recoil of the scar tissue diminished the lumen in a few seconds to 8 millimetres, and by slow degrees this diminished still further. This typical occurrence greatly increases the difficulty of dilating stenoses. There are three possible means of procedure. First, dilatation can be attempted right up to the

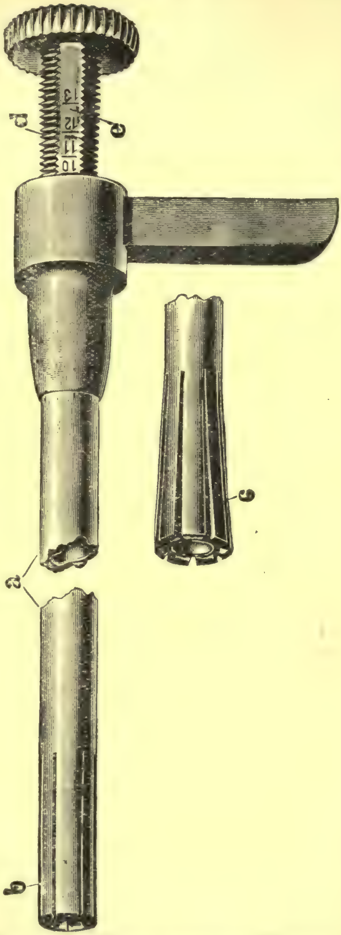


FIG. 112.—BRONCHOSCOPIC EXTRACTION DILATOR.

stenosis below which the foreign body lies; but, as has been seen above, little result will follow on account of the conical end of the bougie. The second method is to dilate by the side of the foreign body, but this is impossible in most cases, and is highly dangerous. The third procedure is to displace the foreign body downwards, and then dilate. This last procedure should always have the first place, for the reasons mentioned above. It need scarcely be mentioned that the introduction of the metal bougies, with the exception of the very fine ones, is performed without the use of the bronchoscope. The distance of the stenosis from the tracheotomy wound is accurately estimated, and the bougie, checked by a scale, is passed into the main bronchus until it reaches the required depth and a sense of elastic resistance is experienced. The pressure exerted must be very gradual and steady, on account of the fits of coughing which tend to displace the bougie until this sensation is clearly recognized. Each bougie should be left in position as long as possible (five to fifteen minutes) before the next size is introduced. The expectoration is usually got rid of through the lumen of the metal tube. The case quoted above has shown that, not infrequently, completely successful bougieing fails to enable the foreign body to be extracted, as the original width of the bronchus can never be reached. Where this is the case, the extraction dilator affords the only help. If the foreign body is a chronic one and time is not pressing, an instrument of the size required can be specially made. The outer tube should be about 1 millimetre less in diameter than the thickest bougie that can pass the stenosis. The length of the tube must exceed by some centimetres the measured distance between the foreign body and the tracheotomy wound. It cannot be gainsaid that the treatment of foreign bodies behind stenoses is one of the most difficult problems that bronchoscopy presents. Unfortunately, the story is by no means ended when extraction has been successful, as the patient still has a scar tissue stenosis and more or less widespread bronchiectasis to be treated. The main point of this treatment must be the production of a permanent dilatation or obliteration, as experience shows that only under these conditions can severe purulent bronchiectatic processes improve and have a practical chance of healing. Unfortunately, the permanent dilatation of foreign body stenoses is impossible by means of bougieing of short duration.

There is one main difference in the elastic properties of cellular tissue and other materials that must be taken into consideration when methods of dilatation come into question. If a weight is hung on a rubber band or steel wire, a definite lengthening proportionate to the weight immediately occurs, and this is not appreciably altered as time goes on. Similarly, after the removal of the weight complete shortening takes place. If a similar experiment is performed on muscles, on fibrous or elastic tissue, there is, immediately after the weight has been put on, a definite stretching, which increases hourly and daily, at first more quickly, and then more slowly. After the load has been removed, the same amount of time is necessary for the tissue to contract to its original length. It is therefore necessary, in cellular tissues, to distinguish the immediate elasticity from the gradual stretching which will react with a prolonged elastic recoil. From the therapeutic point of view it may be considered the rule that prolonged gradual stretching produces a more lasting result than a short forcible dilatation. For the bronchial tree this rule is best observed if permanent tubes of suitable form are placed in the stenosis. In the case which has been dealt with above, silver tubes of the pattern shown in Figs. 113 and 114 were used, and placed in and removed from the stenosis by means of a special introducer.

This introducer is made on the plan of a hollow body forceps, and can be placed and made fast in the tube before introduction by means of a screw in the handle. The small tubes mentioned were made of silver, but for the future I would recommend aluminium, not only on account of its lightness, but especially because such tubes can be worn without producing any reaction. Broncho-intubation is best performed in the following manner: First of all the stenosis is gradually dilated with metal bougies until a diameter of 9 millimetres is reached. The tube itself in this case could not measure more than 8 millimetres at its thickest part, and 7 millimetres at its waist, without running the risk of inflammatory reaction. The introduction, which took place immediately after the last bougieing, was performed through the bronchoscopic tube. This was only possible with the thinnest tubes. For thicker ones, which would not pass through the bronchoscopic tube, another plan was employed. The introducer was passed through the tube spatula and fastened to the stenosis-tube; the tube spatula and the introducer were then passed into the trachea, and the stenosis-tube pushed a little way beyond the end of the spatula. By this manœuvre it was possible to place the stenosis-tube accurately in the stenosis.

When the stenosis-tube was accurately placed, a sensation of "snapping" of the stenosis round the waist of the tube was experienced. The introducer was then withdrawn, and the field of operation inspected. The stenosis-tube must be as short as possible, so as not to block any of the side-bronchi. If the right thickness of tube is used, it can be left free in the elastic stenosis. After some practice the manœuvre became so simple that the tracheotomy wound was closed, and the intubation performed *per vias naturales*. At first the tube was removed every one or two days, on account of the danger of inflammatory swelling or formation of granulation tissue. Later the tube was left in position for a week or more, and then, after three or four days' interval, again inserted. The therapeutic result of this bronchial

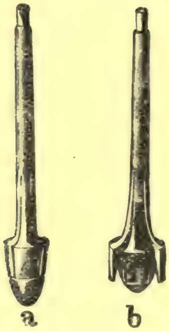


FIG. 113.—TUBE INTRODUCER.

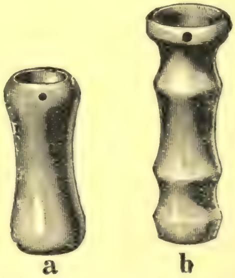


FIG. 114.—STENOSIS TUBES.

intubation was extremely good. At first the purulent expectoration, even after the removal of the foreign body, amounted daily to about 100 c.c., a condition which was not much improved by regular bougieing. When, however, the stenosis-tube was used, the expectoration soon lost its fœtor, and diminished to about 20 c.c. At the end of the first three months the patient was scarcely coughing at all, and was able to dispense with his pocket flask. His general condition improved so much that he was able to return to work. This case will serve to show that an extremely fœtid bronchiectasis due to a foreign body stenosis can get quite well when the original stenosis has been cured. As a rule it is not necessary to apply any form of medicament to the local condition.

Unfortunately, in this case, after leaving out the tube for half a year, the stenosis showed a tendency to contraction, which made itself obvious by increase of cough and secretion. The treatment had therefore to be continued at increasing intervals, and a colleague of mine undertook to do this in the town where the patient lived. I am told that at the present time, three years after the extraction of the foreign body, the stenosis has a lumen, without any further treatment, wide enough to admit a thick pencil. The patient's general and lung condition are so good that he now blows a bugle in the town band.

6. Surgical Treatment of Bronchial Foreign Bodies.

The present position of bronchoscopy, as evidenced in the case just mentioned, will show that surgical interference from outside does not often come into question.* If high and low tracheotomy for foreign bodies are left out, the following procedures remain to be discussed: (1) thoracotomy; (2) intrathoracic tracheotomy; (3) mediastino-bronchotomy; (4) pneumo-bronchotomy.

Thoractomy, or the wide temporary opening of the thorax, can be performed nowadays with pneumatic methods without great danger, and permits a manual examination of the lungs and larger bronchi. If there is no infiltration of the lung tissue, large foreign bodies may be felt even in the main bronchi, and an attempt can be made, without opening the bronchus, to express them upwards within reach of a bronchoscope simultaneously introduced. The chances of the success of this relatively safe surgical procedure are not great, while chronic foreign bodies behind stenoses can scarcely be felt; and even if they were, it remains questionable whether the expression of the object through the stenosis would render extraction more easy. The same holds good of acute cases, in which, indeed, the upper method can scarcely be dispensed with. Nevertheless, it is conceivable that combined endoscopic and palpatory procedure might loosen an impacted foreign body, or displace one in a side-bronchus which was out of reach.

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* *Cf.* Garré u. Quincke, *Grundriss der Lungenchirurgie*, Jena, 1903.

The second procedure—*i.e.*, intrathoracic tracheotomy—needs only a brief mention. Milton* has shown that, after splitting the sternum, the trachea can be drawn up above the arch of the aorta, so that tracheotomy can be performed and the bifurcation exposed. In his case the suture of the trachea presented great difficulties, and the patient died of mediastinitis. For the skilled bronchoscopist I think no indication for this procedure is necessary.

Mediastino-bronchotomy, which is undertaken through the posterior mediastinum, must be regarded to-day as an almost fatal procedure. The danger lies in wounding large vessels which are difficult of access, and especially in the extreme uncertainty of the bronchial suture, which is seldom able to stand violent coughing fits, so that mediastinitis or mediastinal emphysema has always to be reckoned with. There is, further, the danger of wounding important sympathetic ganglia, and of dangerous interference with the vagus, which even in ordinary thoracotomy can result in sudden death. Whether the transpleural route to the larger bronchi is less dangerous cannot well be estimated from the few cases on which it has been tried.

Much more favourable results have been obtained in cases of foreign bodies in the lower lobe bronchioles, which can be reached by pneumo-bronchotomy. On account of the profuse bleeding, the lung is generally opened with the Pacquelin cautery, and the pleura carefully protected from infection by means of plugs. After the foreign body has been successfully extracted, the edges of the wound in the lung are carefully sutured to the opening in the thorax, so as to allow a free drainage, and the bronchial fistula gradually allowed to close. This procedure has the advantage over preliminary suture of the lung that, before opening the lung, a manual examination is possible, and the position of the foreign body may be determined.

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* Quoting from Gottstein, *loc. cit.*

The chances, however, of localizing it in a tissue thickened by chronic pneumonia are very slight. In the eleven cases collected by Tuffier, the foreign body was only found on one occasion. Quincke* reports seven cases in which the foreign body was not once found. In one, however, it was coughed up through the trachea at the conclusion of the operation. It seems to me that in such cases bronchoscopy should always be used as an aid to these operative methods. In the first place, it may be advisable, in the case of a foreign body which cannot be removed, to push it down farther into the peripheral bronchi, and this is usually quite easy on account of the accompanying bronchiectatic condition. Hoffmeister† in one case pursued a collar-stud so far that he was able to push it with the bronchoscopic tube into the pneumotomy wound. A more elegant method would be to push the foreign body with the forceps as far towards the periphery as possible, and then to cut down from outside on to the end of the forceps. If the foreign body is already in one of the smaller bronchi, and cannot be gripped by the forceps, it would be possible to pass a probe down to it, and so localize it for the surgeon. The only trouble is that such a delicate instrument might be displaced during the operation by unavoidable fits of coughing, and, on account of the extreme mobility of the bronchial tree, this could scarcely be prevented by holding the upper end of the probe firmly. I have already referred to the case of a foreign body in the left lower lobe, where pneumotomy was considered, and for which I had a special probe made. The end of the probe is constructed on the plan of my stenosis-tube extractor, but has some sharp teeth on the external surface, which gripped the bronchial wall, and so enabled it to remain in the desired position. Such devices are undoubtedly useful in localizing the foreign body for the surgeon. After an extraction by ordinary bronchoscopic means, the question of external surgery will not often arise, as even a lung abscess shows a tendency to spontaneous healing, and, as the case related above indicates, a high degree of bronchiectasis may be cured by dilating the stricture above it. So long as a bronchial stenosis is present, resection of the ribs is not likely to influence the condition favourably.

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* *Über Pneumotomie Mittlg. a. d. Grenzgebiet,* Bd. 1, 1896.

† *Cf.* Schefold, *Beitr. z. Klin. Chirurg.*, Bd. 43, S. 767.

II. GENERAL ENDOBRONCHIAL THERAPEUTICS.

I do not propose to give more than a brief review of this subject, as my personal experience of it is not very great. As a rule the use of bronchoscopy is essential, because there is no other means by which an exact local application can be obtained.

The most obvious kind of endobronchial therapy, which almost every bronchoscopist has had the chance of practising, is that in which some medicament is applied locally.

Hæmorrhage from the trachea or bronchi, whether spontaneous or after some local removal of tissue, can often be controlled by the application of chromic acid to the site of origin. The pain arising from specific growths, wounds due to foreign bodies or other conditions, are often greatly relieved by a single application of 5 to 10 per cent. silver nitrate.

Apart from these local measures, endobronchial therapy had no more general meaning until Nowotony* accidentally discovered that the use of local anæsthetics and adrenalin for bronchoscopic purposes had a very favourable influence on a case of bronchial

* "Bronchoskopie u. bronchoskopische Behandlung von Bronchial Asthma," *Monatschr. f. Ohrenheilk.*, 1907, 12.

asthma. He found that Galebsky and Tretrop* had a similar experience, and he treated eight cases of asthma after this manner, and successfully obtained a more or less lasting result in seven of them.

The method was applied by Ephraim† on a large number of cases. He confirmed Nowotony's observation, and from a larger experience was enabled to work out the special indications for the method, and a more simple way of applying it.

This is dependent on the fact which Ephraim determined experimentally, that a coloured solution, sprayed into the main bronchi under considerable pressure, diffused itself through the whole lobe of the lung down to the alveoli. If it were inhaled as a coarse spray it would not get much farther than the bifurcation, and even in fine form from a nebulizer its penetration would be very little greater. Bronchoscopy is as a rule not necessary for the use of the endobronchial spray. Ephraim has had an atomizer made which has a movable catheter attachment, which can be introduced through the cocainized larynx under guidance of the laryngeal mirror. If care is taken to observe the centimetre scale, it can be passed beyond the bifurcation into the main bronchus. Proper bending of the body will insure its passing into the bronchus on the right or left side.

It is easy to determine if it is in the desired position by means of auscultation. Ephraim's experience in the endobronchial treatment of bronchial asthma is very extensive, and his last report deals with more than 130 cases. The medicament which he uses is made up of—

Novocain, 2 parts,
Adrenalin (1 in 1,000), 10 parts,
Normal saline to 100 parts.

About 5 to 7 c.c. of this solution is sprayed into the bronchus.

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* "Ueber die Anwendung der Bronchoskopie in 2 Fällen von Asthma Bronchiale," *Monatschr. f. Ohrenheilk.*, 1908, 7.

† "Ueber endobronchiale Therapie," *Berlin. Klin. Woch.*, 1910, No. 27, v. 28; "Grundlagen v. Ergebnisse der lokalen Behandlung chemischentzündlicher Bronchialerkrankungen," *Verh. d. III. Internat. Laryng. Kongr.*, Berlin, 1911.

Its action in bronchial asthma, which may be attributed mainly to the adrenalin, is somewhat as follows: From five to thirty minutes after the injection the feeling of distress and the rhonchi regularly disappear, and breathing becomes unusually easy. This relief is followed, in most cases, by a very free expectoration of thick mucus, which gradually decreases over a period of a few days.

The results obtained vary considerably, according to the type of asthma dealt with. Among the most favourable is that form of chronic bronchitic asthma which is accompanied by emphysema and chronic capillary bronchitis, and gives rise to gradually increasing attacks of dyspnœa. Ephraim has treated 100 cases of this kind, of which 88 remained under observation. Of these, 16 experienced no lasting result (7 of them were only treated once); the remaining 72 were much benefited, and, indeed, 48 were completely free from recurrence from one and a half to eighteen months afterwards, whilst in 18 other cases only a transitory cure, lasting on an average from three to six months, or a permanent slight improvement, was obtained. Judging from these cases, it seems to me that the endobronchial treatment is strongly indicated in the chronic catarrhal type of "asthma," and offers greater chances of cure than any other method. Quite otherwise is it with those cases in which the nervous element is predominant, as these have many periods, which may last months, in which there is a complete absence of symptoms. If in this group cases of definite neurasthenic asthma and cases of hay fever, which are somewhat allied to these, are counted, Ephraim's statistics indicate that, out of 16 definite cases treated, only 6 showed an appreciably lasting result. The prognosis in cases of asthma complicating severe heart failure is just as uncertain.

In addition to asthma, Ephraim has applied the endobronchial treatment to cases of chronic and subchronic catarrhal bronchitis. The medicament mentioned above was the one usually employed, but in marked dry catarrh one or two drops of a 10 per cent. alcoholic solution of iodine was added with advantage; in cases in which the secretion was excessive, a solution of 0·2 per cent. silver nitrate was employed. In 18 out of 22 cases of this kind, even after a single injection, the diminution of the expectoration, and the consequent complete loss of pain, was so marked that further treatment was unnecessary. Purulent bronchitis was in two cases completely cured by means of a 5 to 10 per cent. turpentine emulsion with adrenalin. A patient suffering from bronchiectasis was so far improved after fifteen endobronchial injections that, after a year, only 5 to 7 c.c. of odourless sputum was expectorated, whereas formerly 120 to 150 c.c. of very fœtid secretion had to be got rid of. A second case was similarly benefited.

These cases, which have already called forth considerable confirmatory evidence, can leave no doubt that endobronchial treatment, provided that the indication for it is not too indefinite, can obtain results which no other method affords. That the results obtained by Ephraim do not in any way depend on suggestion seems to me to be supported by the fact that the method fails in those very cases in which the nervous element plays a part, and in the cases in which it is of use the progress is throughout regular, and has a typical character. In conclusion, I would emphasize the fact that in Ephraim's experience the endobronchial treatment has produced no untoward results, and, apart from the cocainization of the larynx, the injection has not caused the patient any inconvenience. In those cases in which silver nitrate and turpentine emulsion were employed, a fit of coughing was occasionally induced, but this was usually of short duration.

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